ILLUMINATING ENGINEERING

MAY 1954

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Temperature Effect on 40T12 Lamp Parameters

Photometer for Large-Area Luminaires

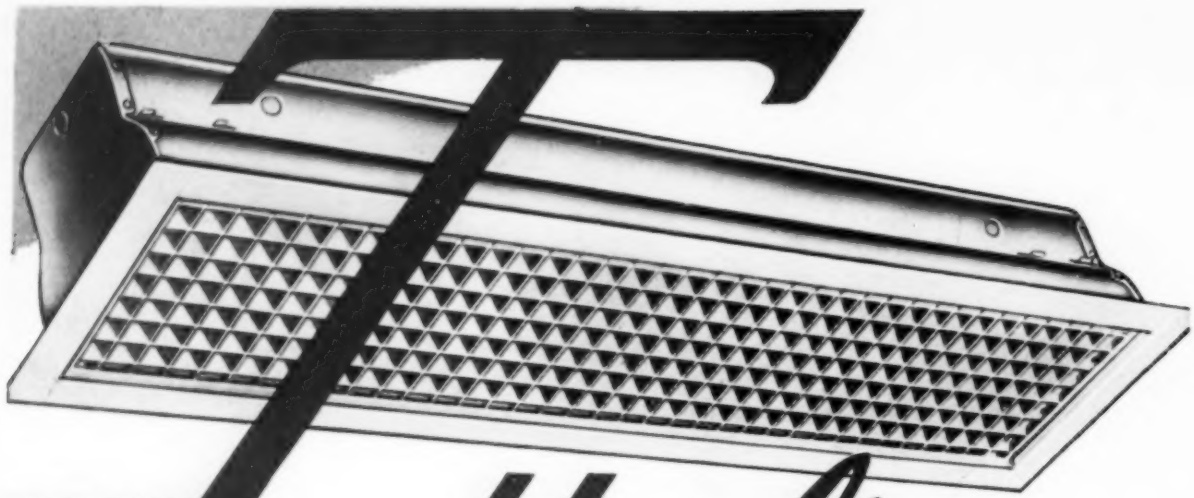
Electrical Measurements of F-Lamps

Damage Hazard in Spectral Energy

Characteristics of Phosphors

Daylight Survey Methods

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY



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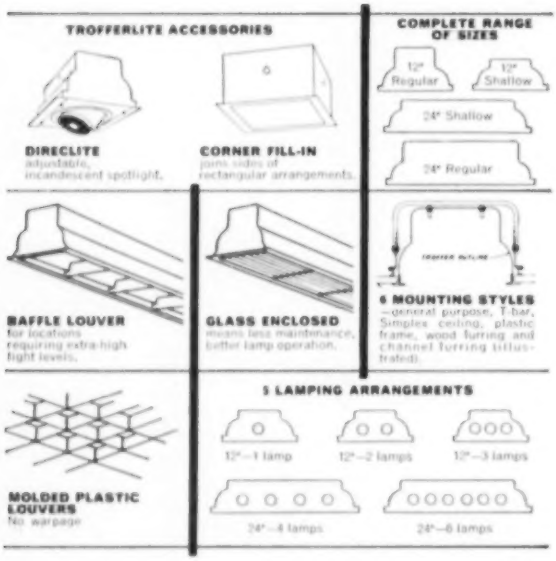

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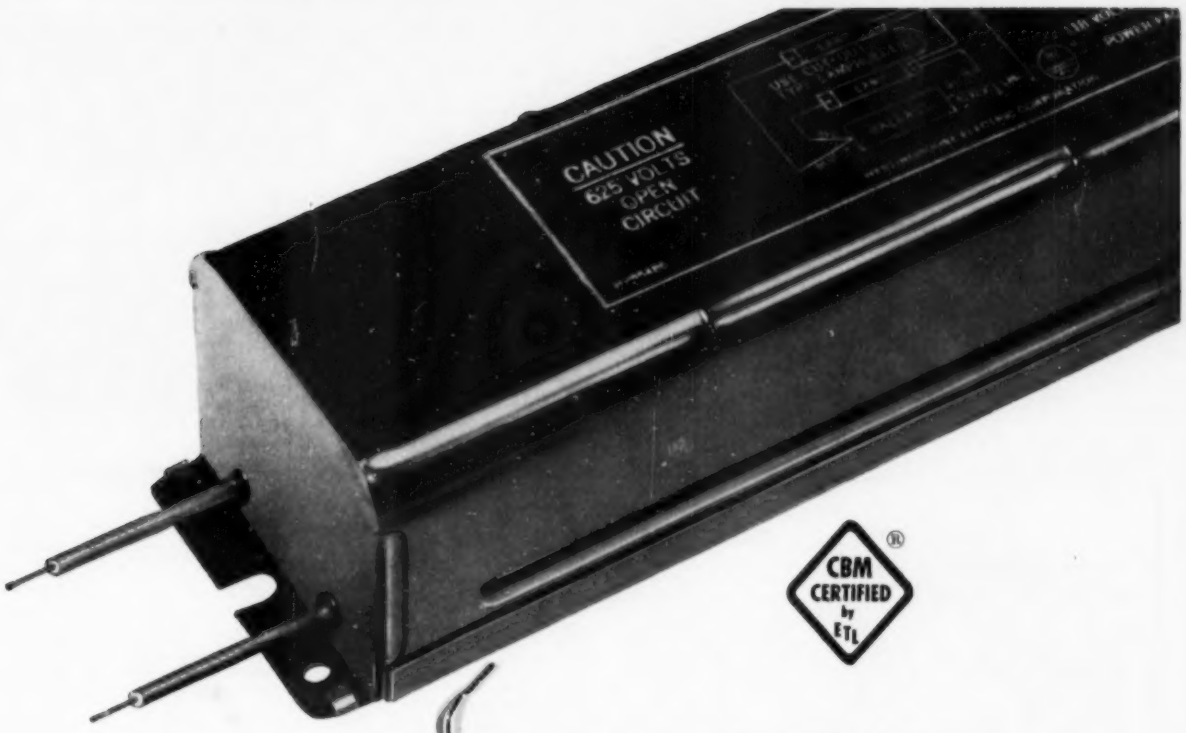

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RATING: WATTS 140 VOLTS 118 ~ 60 CYCLES 60

DATE SELECTED 5/28/58 BY E. J. Fagan ETL ORDER NO. 22463-19
DATE RECEIVED 6/2/58 MFR'S ORDER NO. 2505
DATE TESTED 6/2/58 TESTED BY A.J.C. DATA APPROVED

ETL SPEC. NO.	CIR.	SUPPLY VOLTS	MINIMUM OPEN CIRCUIT VOLTAGE VOLTS AT 200 MA LIGHT	AT 100 MA LIGHT	INPUT TO REFERENCE LAMP(S) VOLTAGE VOLTS	LINE CURRENT AMPS	POWER WATTS	PEAK CURRENT AMPS	RATIO PEAK TO RMS CURRENT	PERCENT CURRENT AMPS	CIR. BALLAST LOSS AT RATED VOLTS WATTS	OVERALL POWER FACTOR PER CENT	HEAD SHAPE	FULL VOLTAGE ACROSS STARTER TERMINALS VOLTS	DI-ELECTRIC STRENGTH TEST	HOT RESTRIKE TIME SEC.	AMBIENT TEMP. °C	HEATING TEST COIL — °C RISE OVER AMB. HOT	COLD	CONDENSER TEMP. °C
Std	Normal				103.0	0.435	40.0													
"		212			107.0	0.396	34.0													
"		224			114.0	0.418	41.8													
"		236			118.6	0.436	44.4													
6-6	Sta.	118	178	185		0.384	37.0	1.030	1.89	0.588										
	Total	"				0.416	48.0				11.0	79.3								
6-7	Sta.	"	176	213		0.386	37.2	0.645	1.64	0.612										
	Total	"				0.414	48.0				10.8	18.4								
6-8	Sta.	106	176				33.6													
	Sta.	118				0.387	37.4	0.550	1.92	0.578										
	Total	"				0.408	42.0				9.6	97.9								
	Sta.	130		213			43.8													
6-9	Sta.	106	176				29.6													
	Sta.	118				0.384	37.6	0.545	1.48	0.668										
	Total	"				0.418	48.0				10.4	77.4								
	Sta.	130		213			44.2													
6-10	Sta.	106	176				28.2													
	Sta.	118				0.382	37.2	0.546	1.48	0.644										
	Total	"				0.412	47.8				10.6	98.3								
	Sta.	130		213			43.8													
Std	Normal				101.0	0.445	40.4													
"		212			107.0	0.396	34.0													
"		224			114.0	0.418	39.8													
"		236			121.6	0.438	44.0													

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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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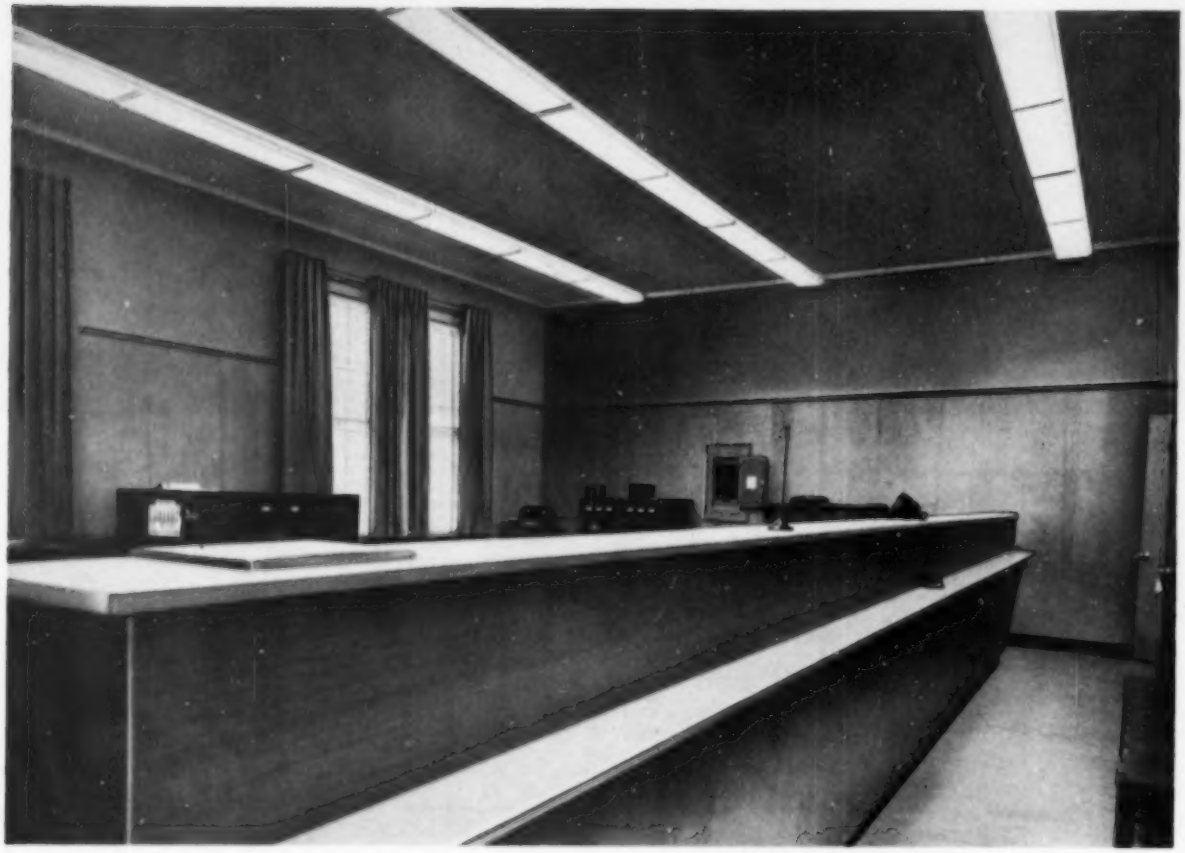

INSTALLATION: Clerk's Office and Small Claims Court, New Britain, Connecticut
ARCHITECT AND ENGINEERS: Mandel Baldesseri
CONTRACTOR: Bassoni Bros., New Britain, Connecticut
ELECTRICAL CONTRACTOR: Gram Electric Co., New Britain, Connecticut
FIXTURES: No. 5328 2-lamp louvered, 35°-25° shielding. Surface mounted.
LAMPS: Standard Cool White
SPACING: 8'-0"
CEILING HEIGHT: 12'-0"
INTENSITY: 85 footcandles average in service
WALLS: Birch plywood, natural
COUNTER AND FLOOR: Linoleum, jaspe color
UPPER WALL: Painted light tan
CEILING: Acoustical tile

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Characteristics of Phosphors

By C. E. WEITZ

One of a series of articles on the characteristics of materials used in the lighting industry. Here many questions on the nature, processing and uses of phosphors are answered by one who has "quizzed the experts."

IN CONTEMPLATING this article on phosphors, the first thought was to try to compose it under the title of "20 Questions." I had read that 20 adroitly posed and answered questions could surround the essence of most any subject. After asking only half a dozen people what questions they might like to have answered about phosphors, I ran up a list of 40 or more . . . none of which could be answered "yes" or "no," or even by a Fleschian composed sentence or two. Perhaps all could be composed into 20 astute questions, but lacking such talent, a few major ones seemed to pop up predominantly:

- What causes phosphors to glow?
- What chemicals make good phosphors and why?
- How are phosphors made or processed?
- How do we stand on phosphor efficiency?
- What can we expect in the future?

In this instance, I am acting as moderator of the panel of questioners, doing a free-lance interpretation of answers supplied by phosphor experts; in other words I will skip the mathematical and chemical formulas and integral equations that dismay my intelligence but which many IES'ers might gulp down and digest with relish.

Few people ever heard of the word "phosphors" before the introduction of the fluorescent lamp, even though knowledge of light-glowing materials is recorded in the earliest historical writings. The word means "light bearer" and was so applied first about 350 years ago when an Italian experimenter noticed that some rocks he had pulverized and heated were so changed that they seemed to glow in the dark. A few years later a new element was isolated. This tended to glow in the dark and even burst into flame on exposure to air and because of its properties was named "phosphorus." It was learned later on that the cause for the glow from these two phosphors is entirely different. The glow from the element phosphorus results from the light given off when it burns in air and is now called chemical (or chemi-) luminescence. This property of ready combustion led to the development of the friction match in 1827. The glow from the Italian phosphor was not chemical at all. In this case the phosphor was just a medium of exchange, like a transformer. It stored and gradually converted the ultraviolet energy present in the sun's rays into visible light long after the sun was down. We now call this by the single word, luminescence. The phosphors used in the early development of the fluorescent lamp did not make use of the element phosphorus at all. Some present-day phosphors happen to use a variety of phosphates — not phosphorus as such. Other phosphors are composed of various inorganic chemical combinations such as silicates, borates, tungstates, sulfides, germanates and others.

While observations of the light-giving properties of hundreds of organic and inorganic materials date back centuries, it may be said that scientific studies and appraisals began a little over 100 years ago. Since then the fluorescing characteristics of liquids and solids exposed to radiant energy — visible or invisible — have become a significant part of the structure of chemistry and chemical analysis. As a matter of fact, "X-rays" were discovered (1895) when radiation from the experimental cathode-ray tube caused some fluorescent materials in an adjoining room to glow. This was about the same time Edison experimented with a fluorescent lamp. Nothing came of Edison's fluorescent lamp, and in the 1921 *I.E.S. Transactions* a scientist wrote ". . . unless someone discovers a means of making luminous bodies that are vastly brighter than the best now known, luminescence may be excluded altogether as a factor in artificial lighting." Nevertheless, fifteen years later fluorescent lamps had become a reality. They had ten times the efficiency of the lamp Edison experimented with, and three times the efficiency of present-day tungsten filament lamps. And fifteen years following their commercial introduction in 1938, it was figured that in the U. S. the lumen hours generated by fluorescent lamps had grown to exceed the lumen hours generated by all other artificial light sources.

Don't get the idea that all this came about through development of phosphors, as implied by

AUTHOR: Lamp Division, General Electric Company, Nela Park, Cleveland, Ohio.

the scientist quoted above. Actually, the key was the development of an efficient source of activating radiation — which turned out to be a very low-pressure mercury-vapor arc lamp. Such sources by themselves generate light at an efficiency of only about five lumens per watt but transform 60 per cent of the electrical energy entering the lamp to invisible ultraviolet (wavelength equivalent: 2537 Angstroms) to which phosphors are tuned.

Prior to the fluorescent lamp, most scientific literature on phosphors was related to luminous screens for X-ray machines and for specialized applications of cathode-ray tubes of one kind or another, such as the oscilloscope. A relatively few pounds of laboratory-produced phosphors took care of all commercial requirements. Efficiency, as judged by the lighting engineer, was of secondary importance. Since then, phosphors have become the heart of several great products of industry whose value in 1953 exceeded two billion dollars — for example, 85 million fluorescent lamps, seven million or more television picture tubes, plus X-ray, oscilloscope and radar screens. Phosphor production today is recorded in tons instead of pounds. Color TV will probably triple phosphor usage for picture tubes and make new precision demands for color balance of phosphor emission.

What Makes Phosphors Phos?

This, of course, is easy for anyone who comprehends and can interpret those interlaced circles and electron orbits so common in electronic and popular science articles. Most people have been exposed to popular astronomy, so they can easily comprehend these diagrams as far as the earth and heavenly bodies are concerned. It takes a little more imagination to conceive that these things are taking place with somewhat the same freedom among components of atoms that are as closely compacted as solid rock. It seems, however, that one must yield to this concept to understand why materials, organic or inorganic, in solid, liquid or gaseous state, give out light under a bombardment of free electrons, or when acted upon by radiant energy.

In these celestial type diagrams, the component electrons are pictured as normally circling the nucleus in a variety of orbits. Turn loose a lot of free energy such as from an X-ray tube, a cathode ray gun, or from a fluorescent lamp discharge, and this energy will displace the electrons blithely circulating in their rock-like orbits and knock them out of position. These displaced electrons receive a lot of outside energy, and, as they vibrate back to their normal position, they give up their energy by radiation at different frequencies like a row of piano strings struck by a hammer.

This secondary radiation will be at a lower frequency because some of the energy of these activating electrons has been lost by contact with the phosphor ions. Thus it comes about that electrons which are displaced by energy of high frequency, such as cathode rays or ultraviolet radiation (2537A in fluorescent lamps), reradiate energy at a lower frequency to which the eye is receptive and we call it light. The inherent loss of energy in transferring from the higher frequency radiation (2537A) to lower frequency visible wavelengths (4000-7000A) is known as the quantum loss. According to the physicists today, this quantum loss or efficiency is in a fixed ratio for each wavelength generated.

Terms — Luminescence, Phorphorescence, or Fluorescence

Production of light electronically is called "luminescence" as contrasted to incandescence where light is produced by heat alone as in a filament lamp. Under luminescence, two terms, phosphorescence and fluorescence, are introduced. There is little agreement as to where one begins and the other ends. Phosphorescent materials are regarded as those which persist in light-giving properties for a fraction of a second or a few minutes or hours after the source of activation has been discontinued. It seems that in this case some of the electrons get trapped and are held up in getting back to their normal orbits. Fluorescence, on the other hand, assumes that the radiation of light occurs at the same time as the exciting radiation. For example, jab your finger into an inflated toy balloon and the rubber snaps back into normal shape before your finger can leave the rubber. Squeeze a heavier rubber or plastic bulb dispenser and it may be several seconds before the bulb resumes its normal shape. This illustrates the difference between fluorescence and phosphorescence, but the reason is not scientifically the same. But that is the idea, at least. There is no precise boundary between phosphorescence and fluorescence and perhaps there is no reason for any precise differentiation. Slight phosphorescent properties are a good thing in fluorescent lamps as this tends to reduce the flicker effect, and this accounts for the difference in flicker between lamps using different phosphors or on circuits of different frequency. Phosphorescent phosphors are important in television picture tubes to carry over the picture images for a small fraction of a second. It must not carry over more than 1/30th of a second because it must be ready to produce new picture responses 30 times a second. Such qualities are the subject of a contemporary phosphor research.

TABLE I.—Fluorescent Lamp Chemicals.

Phosphor	Lamp Color	Exciting Range*	Sensitivity Peak	Emitted Range	Emitted Peak
Calcium Tungstate	Blue	2200-3000	2720	3100-7000	4400
Calcium Silicate	Orange	2200-3000	2537	5000-7200	6100
Magnesium Tungstate	Blue-White	2200-3200	2850	3600-7200	4800
Zinc Silicate	Green	2200-2960	2537	4600-6400	5250
Calcium Halo Phosphate	White	1800-3200	2500	3500-7500	5800
Cadmium Silicate	Yellow-Pink	2200-3200	2400	4800-7400	5950
Cadmium Borate	Pink	2200-3600	2500	5200-7500	6150
Calcium Phosphate	Deep Red	2200-3600	3130	5600-8300	6500
Calcium Phosphate	Blue Ultra	2200-3200	2500-2800	3200-4500	3600
Calcium Phosphate	Blue Ultra	2200-2650	2475	2700-4000	3250

*Limits of measurements.

Fluorescent Chemicals

The first modern fluorescent lamps used willemite ore (natural zinc orthosilicate) from mines in Franklin, New Jersey. Chemical handbooks list the fluorescing properties of thousands of chemicals, both organic and inorganic. Only inorganic materials are used for lamp phosphors. Those most commonly used are given in Table I along with their radiation characteristics.

While many rocks may fluoresce fairly brilliantly in their natural state, the improvements in lamp efficiency due to phosphors have been due to purifying and processing refinements. In other words, the natural materials are taken apart and each element is reduced to absolute purity and put back together again in varying proportions. Strangely enough, while the basic phosphor materials demand the utmost in purity, most of them will not fluoresce until an impurity called an "activator" is added. This is usually a compound of some metal such as copper, silver, manganese, antimony, bismuth, or thallium. These impurities serve not only to trigger the excitation but are the source of the luminescence as well. An activator may, in some cases, as in TV phosphors, assert itself when comprising only one part in ten thousand, but in most lamp phosphors may be as high as several per cent. It is the electrons in the outer orbits of these activator atoms which are the source of the luminescence, as mentioned above. The calcium phosphate for example, in which the activator is crystallized is simply an envelope or housing to hold the activator. The structure of this crystal housing is, however, very important.

It is pretty tough for a person whose knowledge of chemical formulas may be limited to H_2O (water) or NaCl (table salt) to understand fully the chemistry involved in phosphor research, or in the complexities of phosphor making. Only inorganic materials are used as lamp phosphors because organic materials break down under high processing temperatures. There are 3000 or more (the number is ever expanding as research continues) inorganic phosphor compounds to choose from, but only a relatively small number are presently important for lamps and other fluorescent applications. These are:

Sulfides of zinc, cadmium, calcium, strontium
Tungstates of magnesium, calcium, cadmium
Silicates of zinc, calcium, cadmium
Borates of zinc, cadmium
Germanates of zinc, magnesium
Phosphates of calcium, cadmium

The choice of phosphor materials is guided by the sensitivity of the phosphor compound to 2537A radiation. The real test comes from examination of its luminous efficiency, its spectral distribution, its stability in spectral emission. Its ability to withstand high processing temperatures is essential. The extent of its after glow characteristics (sometimes desirable, sometimes not) is also important.

Phosphor Versatility

It will be noted in Table I, for example, that calcium phosphate phosphors show quite a variety of characteristics. Since this is true, they serve as a good example to illustrate phosphor characteristics and the major steps in processing. Calcium phosphate is now the basic phosphor structure for the high-demand types of "white" fluorescent lamps. It represents 85 per cent or more of phosphor tonnage. Remember now that it is the "activator" additive that does the fluorescing. Fig. 1 demonstrates this nicely. The family of spectral emission curves shows the differences in the color quality of light that are caused by the amount of manganese added to the basic calcium phosphate phosphor. The range of these curves extends from no manganese to 1½ per cent. This shows how precise measurements must be to achieve the spectral quality of light standardized upon. And this in turn regulates the lumen output or lumens per watt efficiency ratings that lamp and lighting people are most familiar with. That is the reason why phosphor people talk in terms of grams and milligrams of this and that — why you see precision scales all over the place — each frequently checked

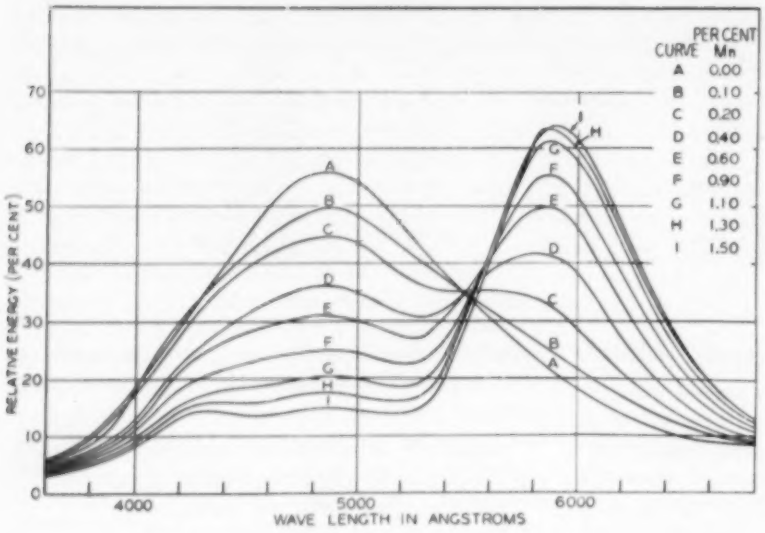


Figure 1. Calcium halophosphate phosphors. (Change in spectral distribution with varying manganese content.)

for accuracy. Pounds and ounces are more familiar terms to me, and I suspect to you, too.

For deluxe white lamps and for the various colored lamps, other phosphor compounds are used, either as phosphor mixes or as special single components.

Chemicals Into Phosphors

Let's follow through the principal manufacturing steps for the big-tonnage calcium phosphate phosphors.

Calcium phosphate is a very common commodity. By itself it does not fluoresce. Bones are 58 per cent calcium phosphate. Natural live teeth fluoresce beautifully under black light. (Dead teeth do not—the activator, whatever it might be, has disappeared.) Mining phosphate rock, most of which goes into commercial fertilizer, is a big business. The raw material costs about a cent a pound or less. But by the time calcium phosphate is processed into fluorescent lamp phosphors, with the addition of other ingredients, it is worth several dollars a pound. Some phosphor ingredients, such as germanium, cost as much as $3.10 a pound. However, the calcium phosphate used in fluorescent phosphors does not derive from the big trade in calcium phosphate rock used for fertilizer, because such natural minerals contain so many impurities. Chemists say that it is easier and less costly to get pure calcium phosphate by other chemical means. They start with calcium chloride powder bought from chemical concerns in 100-pound bags just as you might buy a bag of cement or plaster. It costs about a dollar a bag for the kind you would buy as a substitute for salt on icy streets, or lay dust on dirt roads in place of oil. Grades of various purity can be bought, but the purest of them must further be purified when used as a phosphor.

For the phosphate part, chemical companies sell bags of di-ammonium phosphate. Its source is phosphate rock treated with acid and ammonia. It is used for fireproofing of materials, medicinal compounds and fertilizers. The "food-grade" used costs about 10 cents a pound and this must be further purified for phosphor use.

It is obvious, therefore, that the materials used for phosphors are used for many other purposes, and chemical companies may produce several million tons a year of such constituents as calcium chloride and phosphoric acid. Thousands of tons of other materials in phosphors may be produced for other uses. While commercial grades of some chemicals might perchance fluoresce, they would be of doubtful efficiency. Others might not fluoresce at all, because of the lack of a proper activator. The first step, therefore, is purification. The process varies with each type of phosphor but in general it involves the following steps. Some of the principal steps in phosphor processing and testing are shown in the photo-caption sequence.

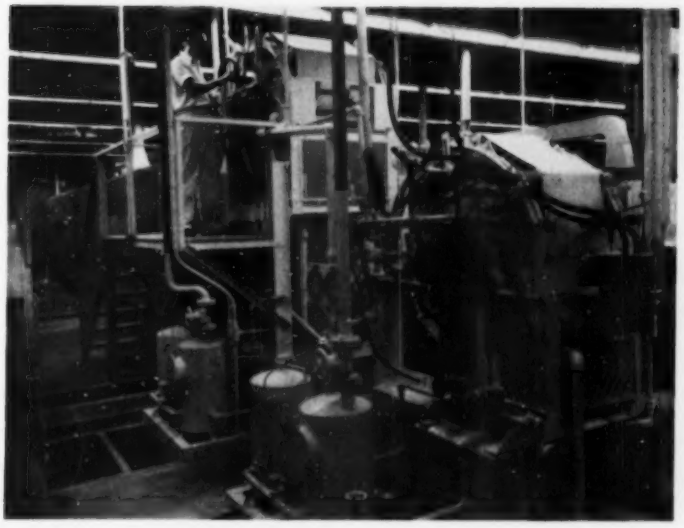
Chemical Purification

To purify commercial grades of calcium chloride the powder is placed in glass lined tanks and dissolved in water preparatory to the removal of impurities. In the purification process de-ionized water is used to be sure it is free from all impurities, particularly iron, since one part of iron in a million parts of phosphor produces detectable loss in lumen output.

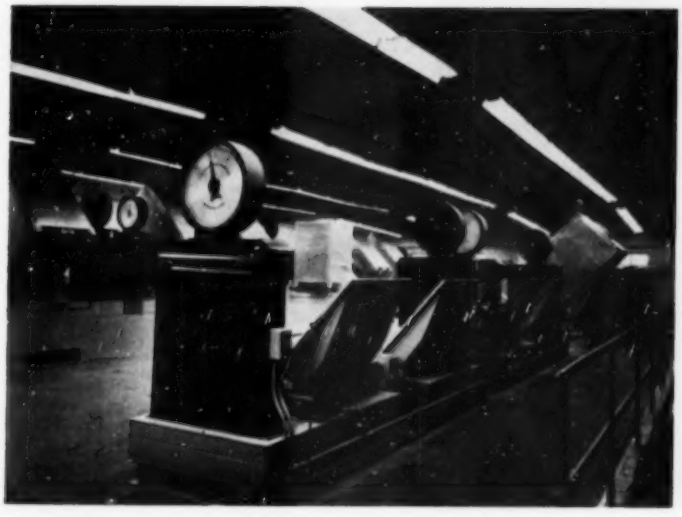
Di-ammonium phosphate is purified and then precipitated with the calcium chloride to yield cal-

Inside a Phosphor Factory . . .

1 . . . stacks of 100-pound bags of calcium chloride and di-ammonium phosphate wait their turn to go into the large glass-lined treating tanks for solution and purification. Precipitated into pure calcium phosphate solution, it goes . . .

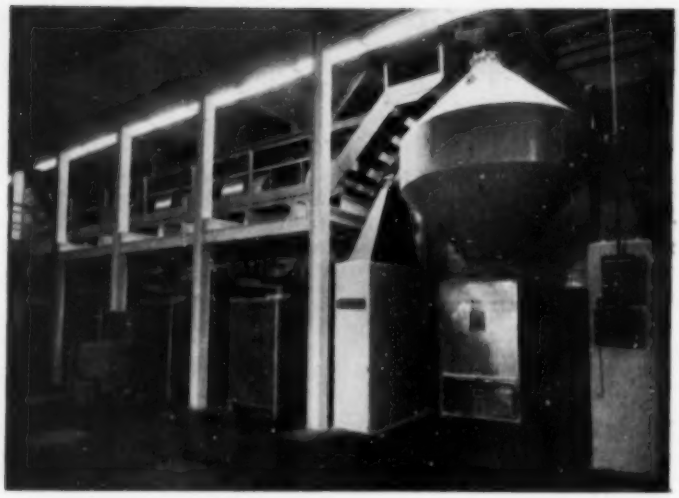


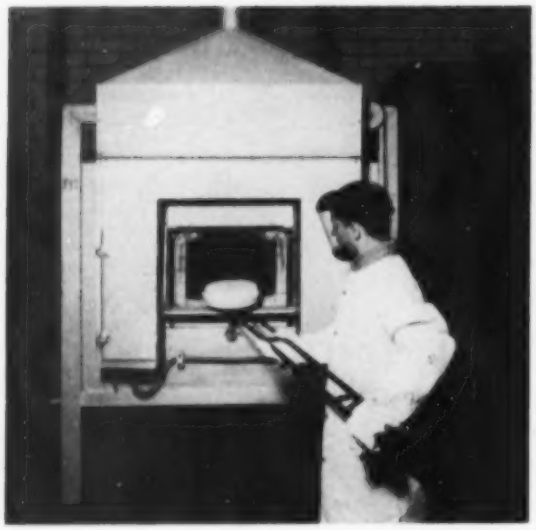
2 . . . into this continuous filter and dryer, out of which comes the flour-like phosphor powder. Put into huge square tanks which go up to . . .



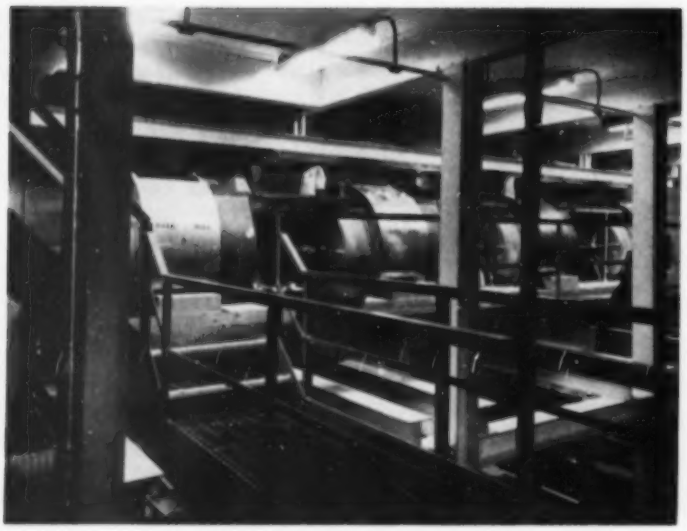
3 . . . a battery of micro-switch weighing machines, from which the powder is screw-fed into the . . .

4 . . . blender, into which go the calcium phosphate and additives of calcium carbonate, and most important, the activators such as antimony oxide or manganese carbonate, also, (if the product requires) fluorine or chlorine. After thorough firing the powder is ready for . . .





5 . . . firing, where the man puts several pounds of the blended powder into silica dishes, which will withstand temperatures over 2500F without melting, and after a slow, high-temperature baking, into the . . .



6 . . . ball-milling machines, where in a couple of hours of churning, flint-rock pebbles break the phosphor crystals to a precise size. The phosphor is now ready for . . .

cium phosphate. Heated to drive off moisture and dried, the calcium phosphate is in a soft, lumpy form which is run through a pulverizer to reduce to finely divided powder.

Blending and Ball-Milling

More calcium in the form of calcium carbonate (like powdered limestone) is also added. So calcium phosphate and calcium carbonate, precisely weighed, go into the blender. To this is added the activators—let us say about two per cent antimony oxide and two per cent manganese carbonate; these are really measured very exactly. The first adapts the phosphor or tunes it to the 2537 radiation as well as creating luminescence. The manganese in varying proportions regulates the light emission as far as the precise spectral quality of the light is desired. (See Fig. 1.) All these chemical components are thoroughly mixed together in the blending machine somewhat like one would do at home with an electric mixer to blend mashed potatoes, milk, butter, salt, pepper, onion or anything else that is needed to meet a standard of taste perfection.

The phosphor blend goes to the ball-milling machines (rotating drums containing marble-sized pellets of flint rock) whose function is to reduce the phosphor crystals to proper size. This treatment lasts for about two hours.

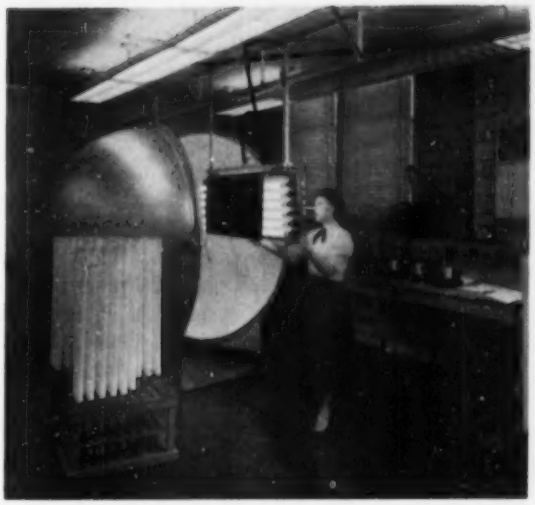
Firing

From the blending machines, a few pounds of the mechanically mixed ingredients are put in silica dishes and loaded on to a conveyor line that leads through an electric oven. The purpose is to synthesize the crystals — that is, to form a single crystal or lattice structure, each of which contains all of the ingredients. The heat treatment lasts for a couple of hours at about 2175°F.

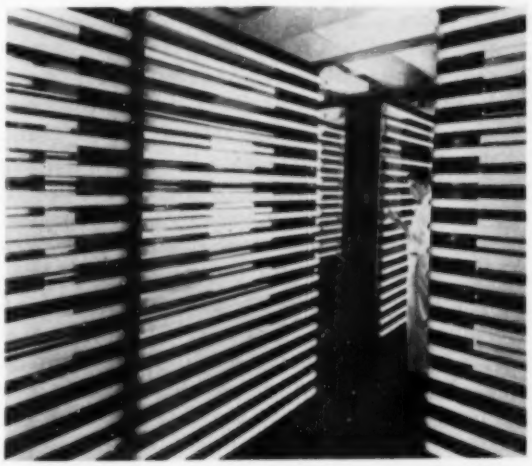
The firing drives off the oxides, carbonates and other volatiles present in the activators. The firing temperatures and time are very critical as phosphor efficiency and spectral distribution is related to both time and temperature. The phosphors won't work at all unless a certain minimum firing temperature is reached. Exact firing time and temperature schedules are followed. Excessive firing may destroy phosphor performance.

Make-Ready for Lamps

After the firing the phosphors are then mixed with a solution of nitrocellulose in an organic liquid. The small amount of nitrocellulose acts as a binder or suspending agent. This phosphor-binder mixture has a light creamy consistency and is again put into a ball-mill to reduce final phosphor particles to proper crystal size, that is, from two to eight microns in diameter This is about the fineness of ordinary flour.



7 . . . test of the powder for brightness and spectral emission, after which test lamps are made up and photometered for lumens-per-watt efficiency. Next . . .



8 . . . sample lamps are burned on test racks; lighted three hours, turned off 15 minutes, until they burn out, to establish nominal average life ratings. Taken off and photometered at intervals during life yields the familiar maintenance-throughout-life curve.

Inorganic phosphors fluoresce only when in crystal form, and some of the crystal lattice structures may be quite complex. For a person who visualizes crystals as in a handful of rock salt, let us say hastily that the chemist measures crystal size in terms of microns, which in my language converts to a millionth of an inch basis. (A micron is roughly 39 millionths of an inch.) When ball-milled too fine, individual crystals may be broken or fractured, and may lose their fluorescent property.

Crystals not milled enough, form masses too large for full exposure to the exciting radiation, and are less efficient. The coating of a single 40-watt lamp will contain several billion phosphor particles.

Testing for Efficiency and Spectral Quality

It will be evident from what has been said that the making of phosphors is a precision job at every step — purification, weighing and mixing, firing time and temperature, and ball-milling to size. Slight variations anywhere along the line can cause detectable differences in phosphor efficiency and finally in the lumen output of the finished lamp. To be sure something hasn't slipped up in the various stages of processing, each batch of phosphor is tested for brightness and color. This is done both on the finished dry powders, and by making up sample lamps which are subjected to spectrometric measurements. As each batch passes its tests, the phosphor is approved for use by the lamp factories.

In the Lamp Factory

Phosphors in finished form may be bagged as dry powder and shipped to the lamp factories, or may be shipped as a suspension, that is, already mixed with the binding solution. Here the phosphor suspension is introduced into automatic bulb filling machines, where the suspension flows down into the glass tubing and coats the inside. It must be checked closely for proper viscosity in order to coat evenly — not too thin — not too thick — an average thickness, let us say, of a thousandth of an inch. If the coating is too thin, the full effect of the 2537 radiation is not utilized; if it is too thick, this diffuse coating absorbs too much of the generated light. A pound of phosphor powder will coat about 125 forty-watt lamps — 3.6 grams per bulb.

After the tubes are coated with the milky-white solution, the final step is lehring — that is, oven-drying to drive off all the binding and suspension materials. Ovens operate at as high a temperature as the glass will stand — somewhere between 500°-600°C. The drying takes only a minute or two. Sample lamps are made up and measured with a reflectometer to check on coating density or thickness.

The photo story, it seems to me, tells pretty well the general steps in making phosphors. It doesn't go into all of the details that the physicists and chemists recited to me. They stressed the importance of all of the little attentions to this and that along the line. For example, specialized phosphors are processed in entirely separate equipment for fear of contamination; air in the factory is electrostatically filtered and completely changed every five minutes — with temperature and humidity regulated. But these are just the sort of attentions that must be given to all sorts of minute details that have brought about the refinements in spectral quality and the increases in luminous efficiency over the past 15 years.

Involved also in the phosphors plant are the instruments for measuring performance all along the line. The spectrograph and analyzer are used by the chemist to determine the degree of purity of the chemicals involved. This makes recordings on photographic film of the characteristic line radiation of various elements. For analysis of the lamp output, the recording spectrophotometer traces off the relative amount of energy (watts) radiated in any small segment (usually 100-Angstrong bands) of the visible spectrum. That is how lamp efficiency is determined.

How Are We Doing on Phosphor Efficiency?

Pretty well. The 96-inch T12 warm white lamp is presently rated at about 71 lumens per watt. Compare this with the theoretical maximum of 105 lumens per watt, theoretically possible if we make no allowances for what we sense as other inevitable losses. The 96-inch T8, 120 ma lamp rates approximately 77 lumens per watt. Let's resort to the familiar bar chart in Fig. 2 and examine this with further comment:

Bar 1. The physicist and the eye have established this limit of 680 lumens per watt for yellow-green light. (Used to be 621 until a few years ago when new calculations set up the higher value.) That means that all energy radiated would be at the single wavelength of 5550 Angstroms, if we could devise a lamp to do this.

Bar 2. But no one wants to live under yellow-green light (sodium vapor lamps produce only in this region). The physicists' pure white light is based on equal amounts of energy (watts) being radiated at each wavelength throughout the visible spectrum. Top efficiency for this condition is calculated to be 220 lumens per watt. And we haven't yet contrived a lamp that would give such a distribution, and there is little need for such. The 388 lumens per watt shown is the maximum efficiency obtainable if every watt put into a lamp was turned into light of the color quality of warm white lamps.

Bar 3. Here's where the quantum conversion loss comes in. The loss in wattage in converting from 2537A incident energy to the longer wavelengths is directly proportional to the ratio of 2537A to the reradiated wavelength (from 2537A to 5074A, for example, the loss would be 50 per cent). In the case of the warm white lamp, the loss is proportional to its integrated energy distribution curve, lower for shorter wavelengths, higher for the longer, but the net conversion efficiency for this particular lamp is 45 per cent. This explains the 174 lumens per watt.

Bar 4. Only 60 per cent of input wattage is converted into radiant energy that acts on the phosphors. Remember the key to the success of the fluorescent lamp was the development of a low-pressure mercury vapor arc that radiated a lot of its energy at a single wavelength to which phosphors

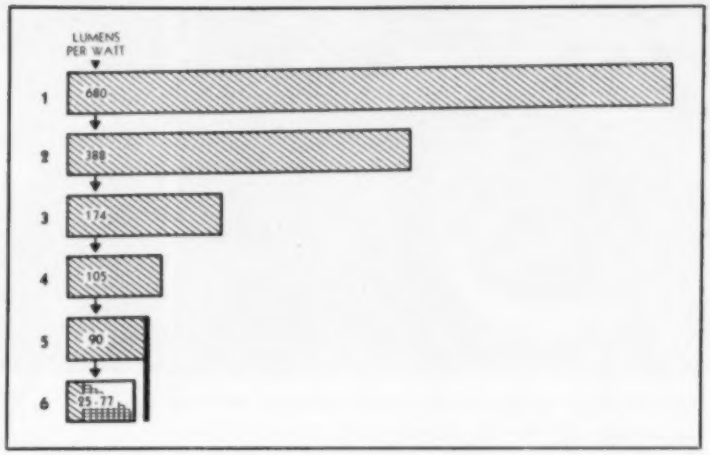


Figure 2. Efficiency losses in standard warm white lamps. (Losses from limit of 680 lpw to rating of approximately 77 lpw are explained in the text.)

could be adjusted to respond. Any improvements over the 60 per cent efficiency known today would be a direct proportional gain, but not related to phosphor potential. Assuming no further advance in discharge efficiency, this knocks down the phosphor part to a theoretical maximum of 105 lumens per watt.

Bar 5. It seems only sensible to suppose that certain of the losses of the light generated by the phosphor are inevitable. No fault of the phosphor — just losses of light trying to get out of the bulb. Maybe a per cent or so improvement might be effected by some unknown scheming. So we arrive at about 90 lumens per watt as far as the phosphor might be concerned.

Bar 6. Efficiency ratings today for the 96-inch T8 warm white lamp operated at 120 milliamperes are approximately 77 lumens per watt. This might apply to all the various lamp types if there were not limiting factors such as lamp watts, lengths, diameters, current loading and other practical considerations not concerned with the phosphors themselves. Today's phosphors, it appears, are hitting between 80 and 90 per cent of theoretical efficiencies. The area of possible improvement lies principally in elimination of phosphor crystal imperfections, that is, in screening out the bad ones, and perhaps tuning the others more critically so that all re-radiated energy falls within the visible spectrum. Minor losses of energy now occur in some re-radiation in the ultraviolet and infrared regions. This energy, of course, does not produce lumens.

What Can We Expect in the Future?

The foregoing chart analysis has been presented at some length, because it has been a favorite topic among lamp and lighting folks to discuss how far we have gone in lamp efficiency, and how far we are below the theoretical maximum. During this 75th anniversary year, particularly, the public is being barraged with the story of artificial lighting progress: Edison's first lamp, producing 1.4 lumens per watt, then up to 4 for the metallized carbon, 8-20 for tungsten, 30-65 for mercury, 25-80 for fluorescent — still short of the 200-300 or 680 lumens per watt held up as a goal. Some folks get the idea that lamp makers could double lamp efficiency any time they were so minded, considering the long gap between the theoretical and today's practical. The fact is that even with the phenomenal fluorescent lamp, we are getting close to the physicists' bumper post at the end of the line as we know it today. But the physicists and chemists caution that some discovery might come about that could obsolete their handbooks.

As of today, one might conclude that we have pretty good fluorescent lamps now — why not let it go at that and not worry about a few more lumens. On the other side of the argument is the fact that people are today buying more than a billion dollars worth of fluorescent light each year. If phosphor research increases efficiency only one per cent, this means 10 million dollars worth of light (minus the cost of improvement research) free to the public. If we could squeeze out another overall 10 per cent lamp efficiency increase, it would mean an extra 100 million dollars worth of light a year at the present going rate of usage and more each year in the future as lamp demand increases.

It will be sensed from the foregoing that among the interrelated variables the phosphor researcher has a million or so combinations to examine critically before he works himself out of a job in his effort to dredge the ultimate in phosphor performance for lamps. In the meantime, new phosphor applications are already bearing down, color TV is with us now — electroluminescence is in infancy — others yet unconceived are inevitable.

[EDITOR'S NOTE: This article is one of a series on the characteristics of materials and services relating to the lighting industry. Previous articles in the series are: "Characteristics of Plastics," "Characteristics of 300-Degree White Baked Enamel Finishes," "Characteristics of Alzak Aluminum," "UL — and the Lighting Industry," "Characteristics of Tungsten," "Calculating Sound-Absorbing Effect of Acoustical Baffles." Future articles are planned for glassware, quartz, etc.]

Looking down at driveway to General Assembly building.

Ramp entrance to the UN garage.

Lighting at the U. N. Grounds

SEVERAL techniques have been used at the United Nations buildings in New York City to light the main entrance and to provide dramatic illumination for the garden area.

Two different types of wall-mounted roadway lights are used at the main approaches — in the driveway in front of the General Assembly building and along the ramp entrance and exit to the UN garage.

Floodlighted trees in garden area. Inset shows unit mounted in concrete block.

On the driveway to the General Assembly building, cast aluminum units contain Alzak aluminum reflectors, with 200-watt incandescent lamps, inner lenses of asymmetric fresnel type and outer prismatic lenses. The unit has a hinged door for easy relamping and an adjusting screw for beam control. These wall-mounted luminaires are mounted below eye level of both pedestrians and motorists to minimize glare and concentrate the light on the road area.

Ramp lighting is by flush-mounted units, especially designed for this installation, so installed that successive beams overlap, minimizing shadows cast by moving cars. These 11 x 13-inch rectangular aluminum housings, with aluminum cover and prismatic lens, use 200-watt standard incandescent lamps.

Highlighting the avenue of trees along the East River side are 44 water-tight floodlights, mounted flush in the ground in concrete blocks — using the principle of lighting foliage from below. This is considered more effective than lighting from above, since the underside of the leaves of most trees is lighter in color than is the upper side, reflecting a higher percentage of light. The floodlights, containing 200-watt lamps, are located in the center of the space between each two trees, so the trees are lighted from two sides. Due to the location of the lights in the beds of ivy, they are inconspicuous during the day.

Photos and data courtesy of Crouse-Hinds Company, Syracuse, N. Y.

Effect of Temperature on Electrical and Color Parameters of 40T12 Fluorescent Lamps

By CHARLES W. JEROME

Introduction

VARIATIONS in ambient temperature have been found to have an appreciable effect on both the color and efficiency of fluorescent lamps. This effect on efficiency has been studied extensively. A partial bibliography is given in the list of references.[1,2,3,4,5] These studies have led to a continual urging of fixture manufacturers to provide adequate ventilation in enclosed fixtures in order to take advantage of the increasing efficiency which the lamp manufacturers have worked so hard to acquire.

The effect on color is not so well documented and heretofore little data were available on which to predict the color shifts which might be expected with the variation of ambient temperature, and what might be done to compensate for it. For example, in an installation of fluorescent lamps in an air-conditioned store, the lamps immediately in front of the cold air inlets were off-color and dim compared to the rest of the lamps.

The present study was undertaken to obtain quantitative data on the performance of present day lamps and to determine the cause of the observed color shifts in an effort to minimize or eliminate them. Only 40-watt T12 lamps were used in this study. The effect of temperature on the performance of other sizes is similar in nature, but the temperature of peak performance may be different as indicated by some of the other investigators.[3,4]

Experimental Procedure

A 40T12 fluorescent lamp was fully enclosed as shown in Fig. 1. Compressed air was passed through a temperature control unit and let into the lamp enclosure at the top. An exit hole for the air was furnished at the bottom of the box. The temperature control unit consisted of a dry ice and acetone bath for temperatures below room temperature, and an electrically controlled air heater for temperatures above room temperatures. The air flow was sufficient to keep the temperatures at top and bottom within 3°C of each other.

A window in the enclosing box at the center of the lamp allowed light to fall on the entrance slit of the spectroradiometer[6] used to measure the spectral energy distribution (SED) of the emitted light. A thermocouple was hung in the air stream at the mid-point along the lamp to measure the ambient temperature and a second thermocouple was fastened against the lamp itself to measure the bulb temperature.

In operation, the ambient temperature was brought to a predetermined point and maintained constant for 15 minutes to allow the system to come to equilibrium. It was found that the system stabilized fairly well in 5 to 10 minutes, but the full 15 minutes was allowed for each setting to insure complete stability. At the end of the stabilizing period, the electrical parameters of the lamp (current, lamp volts, and lamp power) were noted and the SED curve run. A new ambient temperature was then established and the above procedure repeated. This was continued until between 10 and 15 measurements had been made covering the range −10°C to 115°C.

In this study ambient temperature has been used as the independent variable. However, bulb tem-

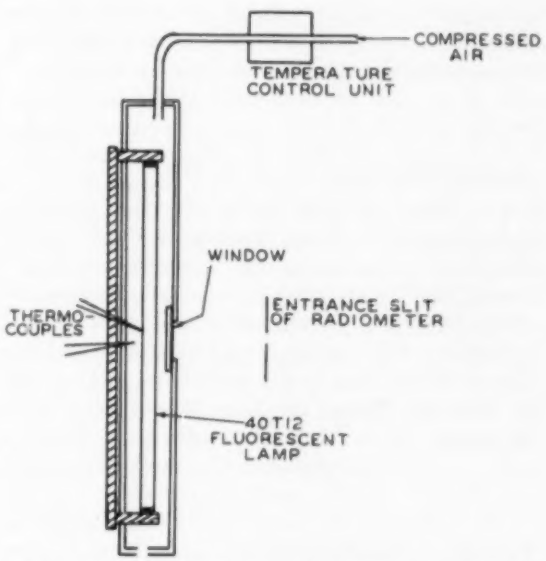


Figure 1. Apparatus for measuring temperature effect.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 14-17, 1953, New York, N. Y. AUTHOR: Sylvania Electric Products Inc., Salem, Mass.

peratures have also been noted in each case. It has been found that the bulb temperature has run consistently approximately 15° above the ambient temperature up to about 70°C ambient. Above that point the difference between the two temperatures decreases becoming zero at slightly above 100°C. Above that point, for the limited range used in this study, the two temperatures appear to remain essentially the same.

The color parameters for the C.I.E. color mixture diagram of the phosphor emission, mercury arc and lamps were computed from the SED curves as has been described previously.[7] In this process, the integral, $\int E\lambda\, \bar{y} d\lambda$, is evaluated for each component and this value was taken as the measure of the relative brightness.

The above results were obtained for a sample lamp of each of the seven standard and deluxe "whites." In the results discussed below, those parameters of the lamps which are common to all (electrical parameters and the color of the mercury arc) were averaged together to establish the value at any one temperature. Since it was not always feasible to establish a particular temperature for these measurements closer than about 5°C, especially with the dry-ice bath, the various parameters for each lamp were plotted as functions of the temperature and from the resulting smooth curve the values at the temperatures desired could be determined. This procedure had the added advantage of minimizing any errors in determining the experimental points through the drawing of the best representative curve.

Since the lamps were not electrically identical, the values of the several parameters were measured in percentages of the value at 20°C. When this is done, good agreement is obtained for the effect of temperature variation on the several lamps.

Results

Electrical Parameters:

The effect of temperature on the electrical parameters of the lamps is shown in Fig. 2. From this figure, it is obvious that an ambient temperature of 20°C, corresponding to a bulb temperature of about 35°C, is the temperature for most efficient operation. The current is at a minimum and the power consumption is at a maximum, and, as will be discussed below, the lamp brightness is at a maximum. It is for these reasons that this temperature has been chosen as standard. From this temperature up to approximately 80°C, the increased thermal activity results in an increasing current, a corresponding decreasing lamp voltage and decreasing power. Above 80°C apparently the

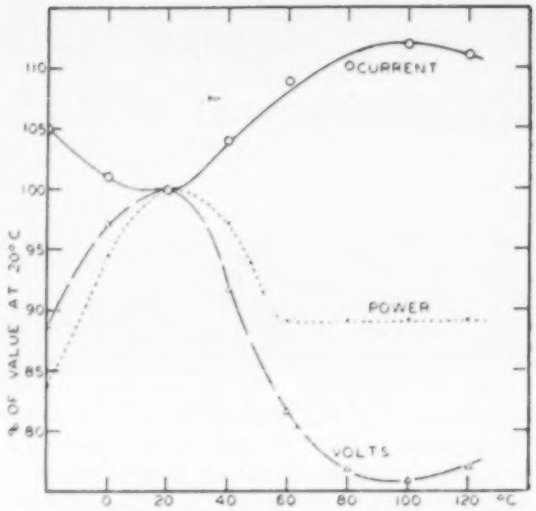


Figure 2. Effect of temperature on electrical parameters (average of all lamps).

increased pressure in the lamp counteracts the increased thermal activity and the parameters stabilize. Presumably at some higher temperatures the increasing pressure in the lamp will reduce the current to extinction. This will cause the lamp voltage to increase, and probably the power consumption will decrease to zero along with the current. A slight indication of the beginning of this trend is shown in the figure.

The increase in current at temperatures below 20°C is attributed to the lowering of the pressure inside the lamp, an effect which is heightened by condensation of mercury out of the arc stream.

Brightness:

The effect of temperature on the brightness of the lamps is shown in Fig. 3. The phosphors in these lamps fall into two categories. The standard whites are single component phosphors, calcium halophosphate; the deluxe colors and the soft white are blends of calcium silicate, zinc orthosilicate and magnesium tungstate. These phosphors all have different coefficients of temperature dependency[8] and it was, therefore, assumed that the effect of temperature would be different for each type in this case. However, it was found that when the brightnesses were expressed as percentages of the values at 20°C, there was a surprising similarity in the dependence of all the lamps.

In the case of the lamps with a blend of phosphors, there are small differences in the temperature dependency of the peaks in the emission contributed by the several components. These differences are sufficient to account for the color changes

discussed below, but are negligible compared to the overall brightness changes.

The results shown in Fig. 3, therefore, are the average values of all the lamps. The phosphor and lamp brightness were very consistent from lamp to lamp, but the mercury arc brightnesses, especially at the high temperatures, varied as much as 15 per cent to 20 per cent from lamp to lamp. This last variation is attributed to variation in the amount of mercury in the individual lamps. With minimal amounts, as the temperature is increased all the mercury may become vaporized and the effect of temperature above that point will be decreased, whereas with an excess amount of mercury the amount in the vaporized state continues to increase with increasing temperature.

As can be seen from the figure, the phosphor and lamp brightnesses are at a maximum at an ambient temperature of 20°C with decreasing brightness on either side of this point. Since the effect of temperature on all the lamps is so similar, this variation with temperature must be due to some other factor than its effect on the phosphor. And the most logical assumption remaining is that the effect must be a secondary one, resulting from the effect of temperature on the intensity of the actinic radiation at 254 millimicrons. This is supported by the data presented in Fig. 4 which shows the effect of ambient temperature on the intensity of the individual mercury lines in the visible spectrum. Three observations can be made from these data:

1. At temperatures below 20°C, all the lines behave in the same manner.
2. Above 20°C, the effect of temperature is different for each line.

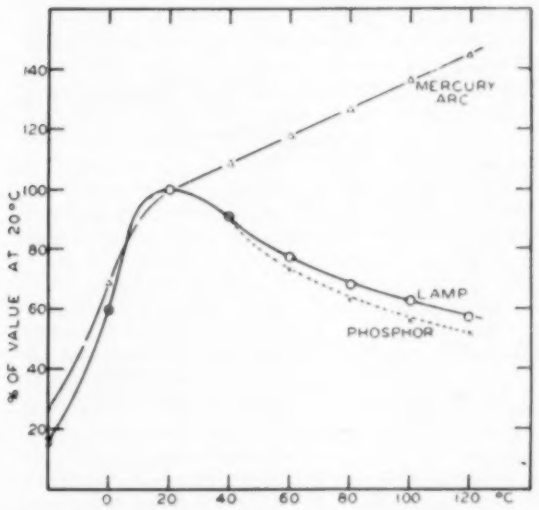


Figure 3. Effect of temperature on brightness (average of all lamps).

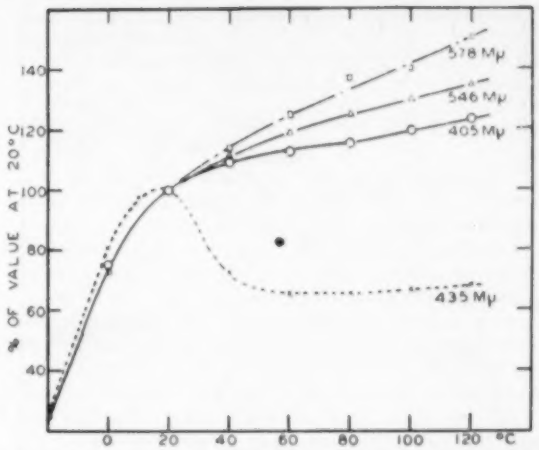


Figure 4. Effect of temperature on intensity of mercury lines (average of all lamps).

3. The effect of temperature on the 435 millimicron line is very similar to the effect of temperature on phosphor brightness.

In view of the individualistic behavior of the mercury lines, the identity of effects below room temperature must again be a secondary effect. This effect is attributed to condensation of mercury out of the arc stream as the temperature is lowered. This causes a decrease in the intensity of all lines in conformity with the observed data.

In view of the behavior of the phosphor brightness, it is assumed that the effect of temperature on the 254 millimicron line is similar to its effect on the 435 millimicron line. This effect is so strong as to overshadow the effect of temperature on the phosphors themselves thereby explaining the similarity of effect on all the phosphors despite their different natures. The 254 millimicron line intensity decreases with decreasing temperatures below 20°C just as the other lines do and for the same reason mentioned above. This explains the decrease in phosphor brightness in this range.

A digression might be in order at this point to observe that a so-called "low temperature" lamp was tested by this means and was found to conform as far as relative brightness was concerned with the regular lamps tested. The only difference between these two types of lamps is the fill pressure. The low temperature lamps have a lower fill pressure to improve their startability at low temperatures. This does result in slightly increased efficiency but the large effect of the temperature variation makes this increase negligible.

Color:

The effect of temperature on the color of the lamps tested is shown in Figs. 5 and 6. In this

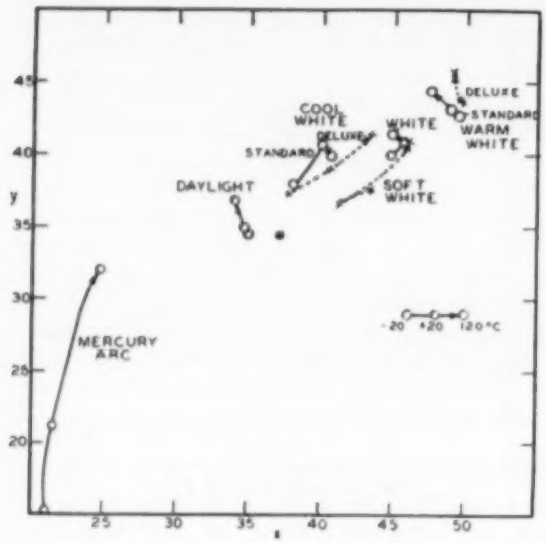


Figure 5. Phosphors and mercury arc on C.I.E. color mixture diagram.

case, of course, the results for the individual lamps cannot be averaged for a single result except in the case of the color of the mercury arc. In the latter instance very consistent results were obtained with all the lamps especially in the middle temperature range. This consistency seems to deteriorate at the extremes of temperature possibly due to an increase in experimental errors in these regions and to the different amounts of mercury in the individual lamps as mentioned above. Therefore, the values for the mercury arc shown in Figs. 5 and 6 are the averages of all the lamps.

These data indicate a fair color constancy for the phosphors, especially for the single component powders. The phosphor blends show a tendency to change towards yellow with increasing temperature. This effect is due to the high temperature sensitivity of magnesium tungstate which decreases in brightness more rapidly than the other components of the blends. This effect is particularly marked in the cases of the cool white deluxe and soft white which have a relatively high percentage of magnesium tungstate; it is not so large in the case of the warm white deluxe since this color has a relatively low percentage of the blue phosphor.

The very large color shift in the mercury arc induced by temperature variation is particularly interesting. This shift is many times larger than the shifts induced in the colors of the phosphors, and accounts for most of the color shift in the lamps. In Fig. 6, the curvature towards the blue at high temperatures in the lines denoting the color shift is due to the increasing brightness of the mercury arc and the decreasing brightness of the phosphor emission in this region as shown in Fig. 3. This effect is not evident in the deluxe and soft white lamps, presumably because the rapid deterioration of the blue component overcomes the increasing arc brightness.

Conclusion

In conclusion, there have been presented data showing the effect of temperature variation on the electrical parameters, brightness, and color of fluorescent lamps. The effect on brightness points out the major conclusion and recommendation derived from this work. That is, fluorescent lamps operate most efficiently at ambient temperatures very close to 20°C. Each rise of 20° above this point results in a decrease in brightness (*i.e.*, light output) of approximately 10 per cent. Therefore, fixture manufacturers can realize a considerable saving in light output by providing adequate ventilation around the lamps to carry off the heat generated in their operation. On the other hand, fixtures for use in low temperatures should be fully enclosed to conserve the generated heat provided such action does not raise the ambient temperature above 20°C.

The color shifts induced by temperature variation are primarily due to the effect on the color and intensity of the mercury arc. At first glance, therefore, there doesn't seem to be much that can be done about this except to try to maintain the

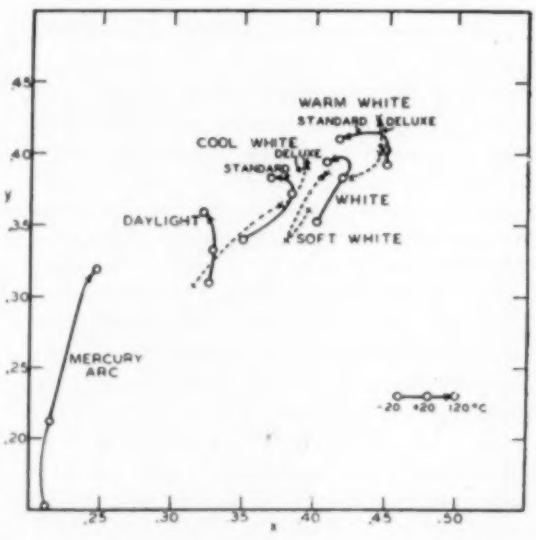


Figure 6. Lamps and mercury arc on C.I.E. color mixture diagram.

ambient temperatures of the lamps at some constant value.

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DISCUSSION

C. N. CLARK*: The information presented in this paper is a welcome addition to our fund of knowledge. The data on light output as affected by temperature are in essential agreement with previous similar investigations, and serve to re-emphasize the strong desirability of designing fixtures enabling the lamps to operate as closely as possible to optimum temperature.

The data on the effect of ambient temperature on lamp color are particularly interesting, not only because of the lamp color appearance problem that may develop when air currents from the ventilating system blow across some of the lamps or fixtures in an installation, but also because the question sometimes arises as to whether the color-rendering properties of lamps operated at abnormally high temperatures, because of high lamp current or poor fixture ventilation, are significantly different from lamps operated at more normal temperatures. Has the author any comment as to what temperature conditions are likely to cause color shifts resulting in significant changes in color rendition?

Other comments and questions come to mind that may be of interest. Several of them relate to the test conditions:

1. Although not specifically stated in the paper, it is to be assumed that the lamps were operated on a lag ballast, since the current would tend to be much more constant in a lead circuit. Would the results be much different for the lead-lag or series ballasts commonly used?

2. Was the rate of air flow in the test box the same at all temperatures and was it measured? The differential between bulb-wall temperature and surrounding air temperature has been shown by Forbes and Diefenthaler (author's reference 3) to be a function of air velocity as well as ambient temperature. Since bulb-wall temperature rather than ambient temperature is directly responsible for lamp operating characteristics, a varying draft would introduce an error when the test results are used to predict operating characteristics in still air or in a constant draft.

3. The fact that the bulb and ambient air temperature are equal at about 100° C. is intriguing. Under this condition, how does the bulb lose the heat it receives from the arc discharge? Is the temperature of the inside surface of the box enough below that of the air inside so that all of the heat received by the bulb can be radiated to the box? Very likely this is the case.

A few statements appear to be somewhat at variance with our own laboratory experience, and may deserve comment:

1. The data in Figs. 2 and 3 taken together indicate maximum efficiency at 20° C. We generally find maximum efficiency at 23-25° C.

2. In the paragraphs under "Electrical Parameters," the terms "increased thermal activity" and "increased pressure" appear to be rather ambiguous. The changes occurring in fluorescent lamps as ambient temperature varies are due almost entirely to changes in the concentration of mercury atoms in the lamps, and total pressure has little effect, so far as optimum temperature is concerned. This is borne out by the last paragraph in the paper under "Brightness," where a lamp with lower fill pressure was tested and "found to conform as far as relative brightness was concerned with the regular lamps tested."

3. The author observes that mercury arc brightness varied by as much as 20 per cent from lamp to lamp, especially at the higher temperatures, although phosphor brightness was very consistent. This large variation of arc brightness is attributed to differences in mercury content of the lamps, such that in some lamps all the mecury is vaporized before the maximum test temperature is reached. Calculations indicate that, in a 40T12 lamp at 120° C., about 7 milligrams of mercury are in the vapor state. It seems unlikely that there would be so little free mercury in a lamp that it is all vaporized at this temperature.

Finally, it may be noted that, although the color shift of the mercury arc is many times as great as the shift of the phosphors according to Fig. 5, its effect on the resultant lamp color is only about 8 or 10 per cent as great as that of the phosphors, because of the low luminous efficiency of the arc. From comparison of Figs. 5 and 6, it might be said that shifts in lamp color with temperature in many cases depend as much on color shift of the phosphor as on changes in the intensity and spectral distribution of the arc.

A. W. WEEKS*: As a Test Engineer, it was my experience that most electrical apparatus was sufficiently stable so that test data could be repeated.

Measurements of fluorescent lamps seemed to contradict this opinion. However, a recent investigation shows that the electrical values of fluorescent lamps can be repeated within about the same limits as incandescent lamps.

The test procedures which will permit this improvement in measurements are available in a new "I.E.S. Guide for Electrical Measurements of Fluorescent Lamps" [see page 267], and I strongly urge the authors of any future papers involving such measurements to consult this Guide.

I believe that closer agreement of test data between investigators will result.

C. M. HOLDEN**: Mr. Jerome has done an excellent job of presenting some very useful material from an application standpoint on the 40-watt T12 fluorescent lamp. Interest in the effect of temperature on fluorescent lamps is increasing as indicated by the number of papers that have been presented on the subject. This particular paper, besides confirming previous data on relative light output, has provided the additional information needed for installations where color is a major criterion.

In the section on relative brightness, it is interesting to

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note that the ambient temperature at which maximum light output occurs is approximately 68°F. It would seem that some consideration should be given to the present lamp rating temperature of 80°F. It is possible that recent changes in lamp materials and production methods may warrant a shift to 68° or 70°.

Information relative to fluorescent lamp behavior is still rather limited, and it is my hope that Mr. Jerome and others will continue their work along these lines so that others involved in lighting applications will have the needed information to better engineer their recommendations.

J. S. FRANKLIN*: The interest shown in the effect of temperature on fluorescent lamps is widespread and indication of the need for such information. This paper is another contribution to our store of knowledge.

My comments pertain to the testing technique employed, particularly temperature measurements. Since the lamp was operated in the vertical position, bulb wall temperature values cannot be compared directly with data in other papers where the lamps were operated in the horizontal position and the thermocouple attached to the under side of the lamp. It is my understanding that the thermocouple was cemented to the lamp. We have found very inconsistent results with this method and rely entirely upon pressure contact which provides consistent and reproducible results. Since it is known that the light output of fluorescent lamps is responsive to changes in air flow over the lamp, it is pertinent to know the air velocity and whether it was maintained constant regardless of changes in the ambient temperature.

CHARLES W. JEROME**: I would like to express my appreciation to the several commentators for their interest in this work. These comments, together with the relatively large number of recent papers on this subject are taken as welcome indications of an increasing awareness of this effect on fluorescent lamp operation.

The effect of temperature on the color-rendering properties of these lamps is expected to be relatively small. Temperature variations change all portions of the spectral energy distributions of the phosphor emissions in a similar manner. Therefore, these variations will cause only very minor changes in their color rendition. There is a considerable change in the distribution of energy among the several mercury lines. But since these are essentially monochromatic and also are only a small part of the overall light emission at temperatures normally encountered their effect on color rendition will also be of a minor nature.

As Mr. Clark has suggested, these data were taken with the lamps operated on a lag ballast. However, since the changes in brightness are attributed to the effect of temperature on the mercury arc, it is expected that very similar, if not identical, effects would be obtained on a lead ballast. Similarly, it is expected that the same effects on color would be obtained whether a lead or lag ballast were used.

The same rate of flow of air was used in all the tests. This rate was constant regardless of changes in the ambient temperature except that a slightly longer line (approximately 10 per cent longer) was used with the dry ice bath than with the air heater. Consequently, there is a slightly smaller air flow in the experiments below room temperature due to the slightly larger resistance offered by the increased length of line. The air flow was not continuously measured, but preliminary tests showed a flow of approximately one cubic foot per minute. With the particular cross section area of the box used, this amounts to an air flow along the lamp of approximately 10 feet per minute, or slightly over one-tenth mile per hour.

As Mr. Clark suggests, the most likely explanation for the decreasing difference between bulb and ambient temperatures with increasing temperature is radiation of heat from the bulb to the wall of the box. I did not intend to imply that these temperatures were equal above 100°C. Actually, however, the difference in this region becomes 1°C, or less, which I have taken to be "essentially the same."

The occurrence of maximum efficiency at 20°C agrees very well with the results obtained by Mr. Holden, (ILLUMINATING ENGINEERING, Vol. XLVIII, No. 12, p. 645, 1953). As the latter investigator has commented above, this change from previous data may be due to changes in lamp materials and production methods. Since the production methods and materials of the several manufacturers are not necessarily identical, this may be the reason for the different results cited by Mr. Clark.

I am inclined to agree with Mr. Clark that in a fluorescent lamp, which normally contains 20 to 50 milligrams of mercury, less than 7 milligrams would be available in the vapor state. Possibly a more tenable explanation of the observed phenomena might be small variations in the density of the phosphor coating.

At low temperatures, the contribution of the mercury arc is a small portion of the total light output of the lamp. However, with increasing temperatures, the brightness of the arc increases while, as explained in the text, the intensity of the actinic radiation at 254 millimicrons decreases with a corresponding decrease in the brightness of the phosphor. Consequently, at the highest temperatures used in this study the contribution of the mercury arc is considerably greater proportionally, amounting more nearly to 25 per cent of the total. This fact, combined with the relatively large color shift of the mercury arc with temperature leads to my conclusion that the latter is a major factor in the color shifts of the lamps observed.

In these tests the thermocouple measuring the bulb wall temperature was held against the bulb by a small piece of electrical scotch tape. The pressure method used by Mr. Franklin was also tried but led to the same results as the scotch tape in the particular arrangement of these tests and at the temperature, relatively close to room temperature, at which the comparison was made. Therefore, the tape was used in preference to the pressure method since it was felt that it provided some protection from the flow of air at the lower ambient temperature past the thermocouple.

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**Author.

Current Industrial Lighting Practice Applied

This Machine Shop features recommended values and the use of illumination principles for comfortable visual environment

By JOHN KERR, JR.

THE principles of proper industrial lighting have now been preached from many platforms at numerous I.E.S. and other meetings. A good many plant managers, as well as all illuminating engineers, are familiar with the elements of these principles, and many have applied them in part or in toto.

An excellent demonstration of their use, however, is in the lighting installation at the new plant of Wright-Hepp Associates, South Hackensack, N. J. With the possible exception of daylight shielding, the area incorporates to a gratifying extent recommended practice for industrial areas.

The 50-foot by 90-foot area is used for light machine work and assembly operations. All surfaces, as well as the luminaires, contribute to the total lighting system. Luminaires are of all-white porcelain enamel, louvered, having 26 per cent uplight and are installed in five continuous rows on 10-foot centers. Each luminaire uses two 96-inch T-12 430ma standard cool white slimline lamps.

The fixtures are suspended 27 inches below the bottoms of the joists so that the bottom of the units is 9 feet 3 inches above the floor. Average maintained illumination, after two months' operation is 64.8 footcandles.

The ceiling is painted a very light yellow of 75-80 per cent reflectance, with the walls and floor a very light smooth concrete finish. All furniture and machines have a light medium green finish; all moving parts are a bright orange.

The combination of quality with quantity has provided a visual environment pleasing to all concerned, especially the people who work there.

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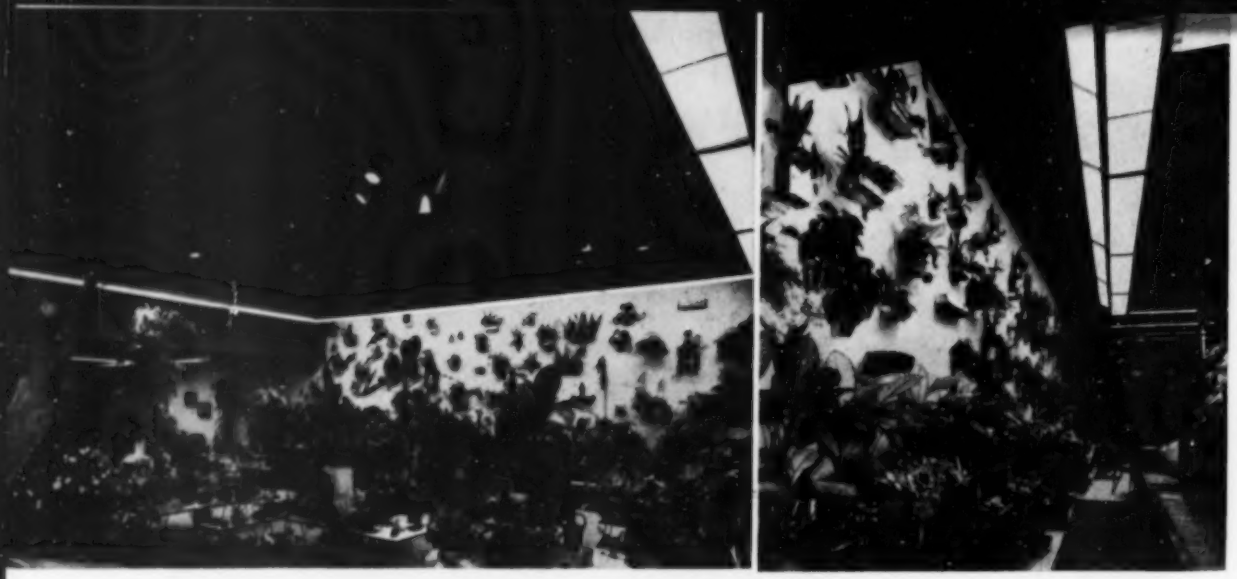

Architects and illuminating engineers alike have long contended that the uniform illumination and balanced brightnesses so desirable in work areas are not suitable for all interiors. Dark ceilings and carefully placed brightnesses in this installation make . . . .

Contrast—a Keynote For a Florist's Display

MAXIMUM contrast — rather than uniform levels of low brightness — was the operative principle in the design of the lighting and color scheme for Crossley's Flower Shop headquarters in the Park Labrea Commercial Area of Los Angeles. The plan was designed to create an apparent luminous atmosphere with the lighting fixtures relatively inconspicuous, to place dramatic emphasis on the plants and flowers. The strong color contrasts of the deep charcoal gray ceiling, the white terrazzo floors flecked with black and gold, and the white display walls make the plants and flowers more vivid in their respective colors — especially when bathed in light which seemingly comes from nowhere. The whole lighting and decorating scheme was designed to achieve maximum attention value from outdoors and a concentrating emphasis on the plants and flowers from inside.

General lighting is from louvered fluorescent luminaires mounted 12½ feet from the floor along the periphery of the main ceiling. These pendent-mounted units have white metal sides and top reflectors, with all light directed downward to brighten the display area and increase the apparent blackness of the ceiling. The louvers provide 42 degrees crosswise and 40 degrees lengthwise shielding. Random clusters of swivel incandescent spotlights also contribute to the blackness of the ceiling as well as accenting certain displays.

A special feature of the shop is the 14 x 45-foot ceiling-to-floor display wall, of perforated metal, painted white enamel with provision for mounting various displays, planters and other merchandise. The primary light source for this wall is a row of special lighting units inclined 30 degrees from the horizontal and totally obscured from normal viewing angles. These fixtures, mounted 14 feet above the floor, have metal louver diffusers and are equipped with four 96T12 lamps each. A portion of the peripheral lighting from the main ceiling supplements the primary source, which results in a nearly uniform vertical distribution of light on the wall. The average maintained level of light on the wall is 84 footcandles.

Ralph C. Didham was architect for Crossley's; Copp and Peabody, Interior Designers; Jackson Brothers, General Contractors; King Electric Co., Electrical Contractors. Photo and data courtesy of Sunbeam Lighting Co., Los Angeles.

Daylight Survey Methods

By E. E. VEZEY
BOB H. REED
BEN H. EVANS

Making daylight surveys on the basis of total daylight factors requires only two illumination meters. The results are practically independent of sky conditions and are sufficiently precise for the comparison of different types of structures. This method is applicable to multilateral fenestrations by covering all of the windows except the one being tested. The method of employing ground and sky daylight factors in making daylight surveys provides a means of separating the illumination at a point into the components contributed by the ground and sky, when light from the surrounding terrain is made use of in design.

IN MAKING daylight surveys in the United States, the usual practice is to make the survey on a day when the sky is overcast or clear so as to avoid rapid fluctuations in the illumination at a given point while the survey is in progress. The final results are then expressed in footcandles for each point under consideration. This information, together with the brightness ratios and a description of the fenestration, constitutes the data from which the adequacy of the illumination might be judged.

This method does not measure a quantity that is characteristic only of the type of fenestration and the physical properties of the room, but contains a variable element which is dependent upon the kind of sky used as a source of illumination. A clear sky or an overcast sky cannot be described with certainty; therefore, it is difficult to compare two surveys made at different times of the same situation and still more difficult to make a comparison of different types of structures. Neither is it possible to separate the illumination at a given point into the components that arise from the ground and the sky. These components may be nearly equal in some cases and the illumination at the back of the room may be greatly improved by properly using the light that arises from the ground adjacent to the building.

In this paper two methods of making daylight surveys will be presented. The first method will eliminate the necessity for defining a standard sky and will use daylight factors in expressing the results of the survey. The second method will provide a method of separating the illumination at a given point into the component that arise from the ground and from the sky.

First Method — Total Daylight Factors

It is a common practice in Europe to express surveys in terms of daylight factors which according to Gunner Pleijel, Stockholm, Sweden,[1] are defined as the ratio between the illumination at a given point on a given plane to the illumination produced on a horizontal plane by a sky of uniform brightness. Thus the number assigned to a given point in a room is not expressed in footcandles, but by a nondimensional number which depends only upon the fenestration and the physical characteristics of the room. This mode of expressing daylight surveys, eliminates one of the troublesome variables caused by one's inability to realize in practice a standard sky.

In developing the first method of making daylight surveys, it was assumed that there is a nearly constant ratio between the illumination falling on a plane at a point in a room to the amount of luminous flux falling on the plane of the fenestration. One should expect that this ratio should vary about some mean value because of the nonuniformity of brightness of the sky and surrounding terrain. The only question to be answered is, what is the magnitude of this variation? If this variation is sufficiently small and occurs at such infrequent intervals as to make it possible to compute an average value without taking an unreasonable number of observations, then a method based upon the above assumption would be sound in principle and easy in practice.

For the purpose of determining the dependability of a method of making daylight surveys based upon the above assumption, the daylight factor is defined as the ratio of the illumination at a point on a horizontal plane in a room to the illumi-

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nation incident on the plane of the fenestration under consideration. Note that the daylight factor is not defined for the case where the sun is shining on the fenestration. However, the definition could be used for that case also, provided the fenestration was of the diffusing type which allows no direct sunlight to enter. The method is applicable to multilateral fenestrations if each fenestration is considered separately. This could be done by covering all fenestrations except the one under consideration.

Method of Making Survey

Data were collected by calibrating two recorders to read footcandles. The cells used were Weston Model 856RR-V provided with cosine correction. The scale on the recorders was calibrated by comparison with a Weston paddle type meter Model 430. The meter cell was provided with cosine correction and Viscor filter and had been checked for accuracy of calibration against a standard lamp.

It may be mentioned here that it is not necessary to calibrate the instruments to read footcandles when this method is used in making surveys. It is only necessary that the meters give identical readings when exposed to the same luminous flux.

One cell was placed in the plane of the window outside of all obstructions that might be considered a part of the fenestration. Anything that limits the amount of light that passes through the fenestration should be considered a part of the fenestration, whether it be louvers, overhangs, or shrubs. The other cell was placed at the test point in the room, 30 inches above the floor. The recorders were set on the same line on the paper and started simultaneously. The graphs produced simultaneous records of the variation of the illumination at both stations. No particular attempt was made to choose the kind of day when the records were taken. All types were used: clear, overcast, and partly cloudy.

The daylight factors were determined from the records made by the recorders by considering only points on the graph where both cells indicated steady states. These points occurred either at maxima or minima on the graphs. This had to be done because the recorders used are slow in coming to new values and require a few seconds to reach a steady state after a change in the illumination. It is believed that more consistent values may be obtained by the use of two meters that have the same time constants and that have been compared for consistency.

A study was made of the variation of the daylight factors for two rooms in an experimental building of the Texas Engineering Experiment Station. This building is located in a large field far away from other buildings or trees and may be oriented at any angle to the meridian. The fenestration of Room No. 1 is directional glass block with the conventional vision strip, while Room No. 2 has plain glass windows. Both rooms* are provided with venetian blinds that may be used to cover the entire area of the clear glass portion of the windows. It is to be emphasized that the two rooms described above were used in these tests simply because they employed commonly used, but quite different types of fenestration. No comparison of the relative merits of these two types of fenestration, or of the products involved is intended or implied.

*These two rooms, designed originally for another purpose, were made available for this study through the courtesy of the Kimble Glass Company and the Pittsburgh Corning Corporation.

Chart No. 1.—Data from Survey

METHOD I	ROOM NO. 1											
	POSITION 1							POSITION 2				
	1	2	3	4	5*	6	7	8	9	10	11	12
Date	Feb 26	Feb 27	Mar 2	Mar 6	Mar 13	June 5	June 9	Mar 6	Mar 6	Mar 13	June 5	June 9
Time	2:00 to 5:50	9:10 to 5:00	8:30 to 1:50	1:30 to 4:30	9:55 to 10:45	9:30 to 10:00		8:30	8:30	11:30 to 1:40		
$\frac{E}{E_o}$ = Daylight Factor	.083	.077	.075	.072	.082	.073	.066	.023	.024	.023	.020	.020
Maximum Deviation from Average Value of the Daylight Factor	18%	15.5%	17%	9.7%	18%			13%	8.3%	17%		
Number of Times Maximum Deviation of Daylight Factor Occurred	1 in 12	1 in 29	1 in 43	1 in 17	1 in 35	Single Obs.	Single Obs.	1 in 16	5 in 26	1 in 25	Single Obs.	Single Obs.
Maximum Deviation from Average of Daylight Factors on Different Days	6.4%	1.3%	3.9%	6.8%	5.1%			1.3%	2.6%	1.3%		

*Data taken by meter instead of micromax recorders.

Two positions, position 1 and position 2, were studied for Room No. 1. Position 1 was seven feet from the center of the windows and position 2 was 19 feet from the window near the back of the room.

From Chart 1, it may be observed that for position 1 of Room No. 1 the maximum deviation from the average of a single determination of the daylight factor was 18 per cent and that the maximum deviation from the average of five sets of daylight factors was 6.8 per cent. This last statement is significant, for the sets of daylight factors were taken at widely different times under a great variety of sky conditions. It is the opinion of the authors of this paper that any method of making daylight surveys which gives results that agree to within 10 per cent is satisfactory.

To determine the reliability of a small number of observations in arriving at an average value for the daylight factor, a set of 38 observations were analyzed. These data were for position 1 in Room No. 1 and were taken between 9:30 and 11:00 a.m., February 13, 1953. These observations were divided into groups of ten arranged so that each group of ten, except the first and last group, included five observations of each adjacent group. The average of the 38 observations was .082. The average of each group of ten in the order of grouping was .081, .079, .081, .084, .085, .082, and .083. The maximum deviation from the average of 38 observations was three parts in 82, which gives 3.65 per cent. This demonstrates that it is not necessary to make more than ten observations at a given point to insure sufficient accuracy in arriving at the daylight factors.

The results for position 2 of Room No. 1 are in closer agreement than those for position 1. This is to be expected, for points farther back in the room see less of the sky and receive a greater part of the light from interreflection than do points near the windows.

On examination of the daylight factors for position 2 of Room No. 2, it is seen that there are slightly greater variations in the daylight factors than for the corresponding point in Room No. 1. This also may be expected for each point sees through nondiffusing material a large portion of the sky and for that reason reflects the variations in the daylight factors that occur because of the nonuniformity of the brightness of the sky.

Nothing new is to be recommended in this paper in regard to brightness ratios, except to suggest using brightness to illumination ratios.[2] The magnitude of variation of the ratio (Brightness/Illumination) is illustrated by a set of 30 ratios taken in the glass block side of the experimental building. For brightness readings a spot was chosen on the glass block about 30 degrees above the horizontal from the observation station at the center of the room. Observations were made at intervals from 9:19 a.m. to 1:16 p.m. The sky was partly cloudy and the brightness of the glass block varied from 200 to 860 footlamberts. The average value of the ratio for the 30 observations was 7.4. The maximum value was 8.6 which gives a maximum deviation from the average of 1.2. The maximum per cent variation of the ratio is then 16.2 per cent.

Data were collected for other situations. For an office, brightness to illumination ratios were taken from 3:00 p.m. to 4:20 p.m. and of 15 observations, the average value of the ratios was 1.32 and the maximum per cent variation from the average was 13.6 per cent. During the period of making the observations the brightness of the test spot varied from 120 to 33 footlamberts and the illumination at the observers' station varied from 86 to 30 footcandles.

In any data observed, it is found that the maximum per cent variation of the ratio brightness to illumination is not too large to make a mean value of from five to ten ratios an acceptable criterion for the quality of illumination.

Second Method — Ground and Sky Daylight Factors

In an article by J. W. Griffith, O. F. Wenzler, and E. W. Conover, published in the January 1953 issue of ILLUMINATING ENGINEERING,[3] results were given of a method which separated the effects of ground light and sky light. Details of the method were not given, and it is assumed that the work was done on models under an artificial sky.

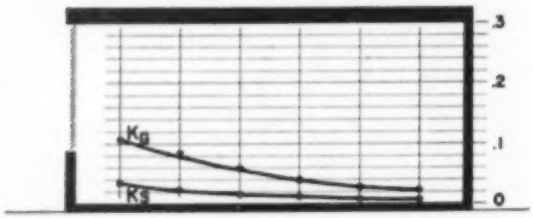
Using Total Daylight Factors.

ROOM NO. 2 POSITION 2							
13 Mar 11	14 Mar 13	15 Mar 13	16* Mar 13	17 Mar 16	18 Mar 17	19 Mar 18	20 Mar 19
9:50 to 2:00	9:50 to 3:30			11:00 to 6:30	1:40 to 4:55	8:50 to 4:40	8:40 to 4:35
.040	.043	.041	.042	.039	.043	.045	.046
20%	14%	14.5%	14%	20%	14%	20%	6.5%
1 in 30	1 in 32	1 in 16	1 in 42	1 in 45	3 in 30	1 in 38	3 in 44
5.7%	1.4%	3.3%	1.0%	8.0%	1.4%	6.1%	8.5%

Room No. 2 — Windows facing north.

Chart No. 2.
ROOM NO. 2
ALL BLINDS ADJUSTED UP 45°

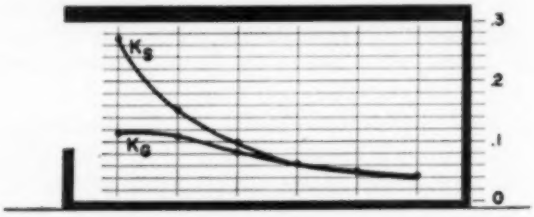
	Station	1	2	3	4	5	6
K_g	1	.1090	.0860	.0625	.0420	.0313	.0242
	2	.1040	.0840	.0535	.0358	.0255	.0206
	3	.1010	.0840	.0614	.0410	.0294	.0225
	Avg.	.1050	.0850	.0590	.0400	.0290	.0220
K_s	1	.0367	.0253	.0168	.0115	.0085	.0075
	2	.0334	.0226	.0197	.0135	.0106	.0088
	3	.0407	.0264	.0176	.0117	.0098	.0092
	Avg.	.0368	.0248	.0180	.0122	.0100	.0085



Graph 1.

Chart No. 3.
ROOM NO. 2
NO SHADES

	Station	1	2	3	4	5	6
K_g	1	.1220	.0730	.0700	.0724	.0432	.0408
	2	.1110	.1260	.1000	.0745	.0615	.0494
	3	.1430	.1300	.0800	.0450	.0460	.0380
	Avg.	.1250	.1090	.0830	.0640	.0500	.0430
K_s	1	.2720	.1820	.1060	.0590	.0458	.0392
	2	.2280	.1370	.0930	.0595	.0414	.0356
	3	.2530	.1320	.0940	.0710	.0480	.0420
	Avg.	.2500	.1500	.0980	.0630	.0450	.0390



Graph 2.

The Texas Engineering Experiment Station has been working for the past two years on a method which may be applied to models under an artificial sky or to daylight surveys made on buildings in the field.

This method is based upon the assumption that the illumination at a given station at a given instant is the sum of two terms. One term being the product of a factor and the illumination on the fenestration from the ground and the other the product of a factor and the illumination on the fenestration from the sky. This statement reduced to algebra is

$$E = K_g E_g + K_s E_s \qquad (1)$$

where E represents the illumination at any point in the room. K_g is the factor for the ground, E_g is the illumination on the fenestration from the ground, K_s is the factor for the sky and E_s is the illumination on the fenestration from the sky. K_g and K_s are called ground daylight factors and sky daylight factors, respectively.

It is important to realize that K_g and K_s are constants for a particular point in the room at a particular time. The time element is involved because the distribution of the brightness of ground and the sky vary from instant to instant. However, these fluctuations of the distribution of the brightness of the ground and sky produce only minor variations in the values of K_g and K_s. Note that when both the light from the ground and the light from the sky were considered together, as was done in the first part of this report, the maximum fluctuations of the daylight factor were only about 20 per cent, and the maximum fluctuation occurred approximately once in ten observations.

In Equation 1, it is possible to measure E, E_g, and E_s directly, which leaves K_g and K_s to be evaluated. This is done by taking two sets of data for Equation 1 which will give a wide fluctuation between the values of E_g and E_s. This is best accomplished on a day when the sky is covered approximately 50 per cent by cumulus clouds. The more nearly uniform the clouds are scattered over the sky, the better. There are two reasons for selecting this kind of sky: (1) because the average distribution of the brightness of the sky will remain nearly constant over long periods of time, thus minimizing the fluctuation in the value of K_s, and (2) when the cumulus clouds are quite numerous the ground will be alternately quite bright and dark at frequent intervals. This makes a large variation in E_g between two sets of data possible. A little thought will show that the larger the variation in the E_g values for two sets of data, the more accurate are the determinations of K_g and K_s.

While the functional relation expressed by Equation 1 is exact, it must be remembered that E, E_g, and E_s are measured quantities and for that reason are subject to certain errors that cannot be eliminated entirely, only minimized by careful work; therefore, great care should be exercised in calibrating the instruments and in their use.

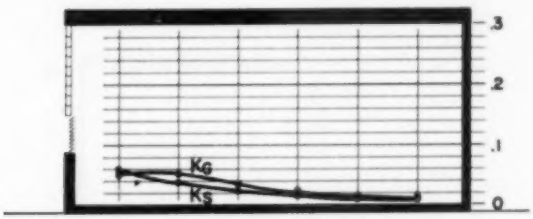
Three illumination meters* are necessary; one to

*Two of the meters were loaned by the Pittsburgh Corning Corporation.

Room No. 1 — Windows facing north.

Chart No. 4.
ROOM NO. 1
VISION STRIP BLINDS ADJUSTED UP 45°

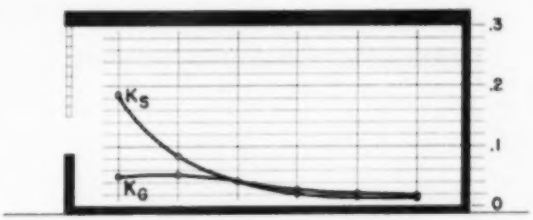
	Station	1	2	3	4	5	6
K_g	1	.0495	.0492	.0320	.0222	.0140	.0114
	2	.0600	.0582	.0408	.0258	.0144	.0139
	3	.0522	.0500	.0345	.0243	.0176	.0127
	Avg.	.0540	.0520	.0360	.0240	.0153	.0127
K_s	1	.0700	.0436	.0212	.0127	.0156	.0117
	2	.0420	.0363	.0255	.0178	.0137	.0094
	3	.0673	.0412	.0281	.0186	.0135	.0102
	Avg.	.0600	.0400	.0250	.0164	.0143	.0104



Graph 3.

Chart No. 5.
ROOM NO. 1
NO SHADES

	Station	1	2	3	4	5	6
K_g	1	.0228	.0372	.0374	.0310	.0225	.0189
	2	.0694	.0628	.0465	.0575	.0256	.0190
	3	.0573	.0563	.0419	.0336	.0206	.0164
	Avg.	.0500	.0520	.0414	.0405	.0216	.0180
K_s	1	.1920	.0897	.0360	.0277	.0214	.0173
	2	.1850	.0766	.0423	.0173	.0190	.0143
	3	.1860	.0810	.0453	.0278	.0193	.0156
	Avg.	.1870	.0825	.0409	.0243	.0195	.0157



Graph 4.

be used at the station in the room, one for measuring the illumination from the ground, and one for measuring the illumination from the sky. All three meters should have the same type of correction and be adjusted so that they give identical readings under similar situations. They should also have the same time constants.

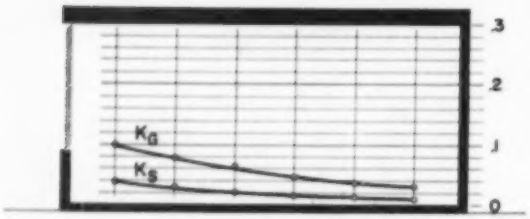
Sky light is separated from the ground light by a horizontal semicircular plane edged with a rim which projects vertically above and below the plane One cell is placed above the plane and one below the plane with their centers on planes which pass through the edge of the rim. The upper cell sees one-half of the sky above the horizon and lower cell sees that part of the terrain below the horizon. The whole device is painted matte black. The cells are adjusted relative to the rim so that the sum of the reading of the cells is equal to the reading of a single cell placed in the plane of the fenestration which sees both the sky and the surrounding terrain. Experience indicates that the position of the device separating the sky light from the ground light is not critical so long as it is placed approximately eight feet above the ground. The results of four surveys are given by Charts 2, 3, 4, and 5 and corresponding Graphs 1, 2, 3, and 4. The graphs in each case are plotted from average values taken from the charts. The stations for which K_g and K_s were determined for each type of fenestration were six in number. Station 1 was three feet from the fenestration and stations 2, 3, 4, 5, and 6 were 7, 11, 15, 19, and 23 feet from the window, respectively. All stations were along the center line of the room. The reflection factors were: ceiling 80 per cent, walls 60 per cent, and floors 40 per cent. All readings were taken on a horizontal plane 30 inches above the floor.

All four graphs indicate that the ground daylight factors for points near the back of the room are larger than the sky daylight factors. This does not necessarily mean that more illumination is furnished by the ground at these points. The ratio of E_s/E_g for a cloudy day when the ground is in shadow may be as high as 7 or 8 while for a nearly clear day when the ground is brightly illuminated the ratio may be nearly unity. The value of this ratio depends upon the reflectivity of the surrounding terrain, but the ground daylight factor does not unless the terrain undergoes great localized variation in reflectivity. The reflectivity of the terrain for the building under test was approximately 40 per cent.

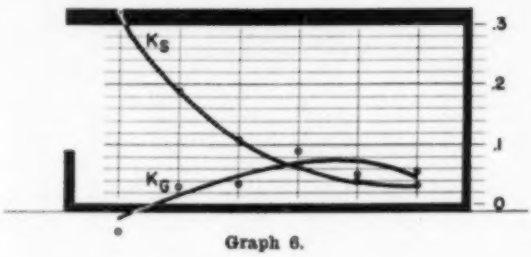
The data used in constructing Graphs 1, 2, 3, and 4 were collected from February to March 1953. The instruments used for obtaining the sky and ground illumination were Weston Model 856RR-V provided with cosine correction and were attached to Leeds and Northrup Type P galvanometers, the scales of which were calibrated to read footcandles against a Weston paddle type meter having the same corrections as the above cells. The data were taken on days when the sky was partly covered by cumulus clouds. The windows faced north.

Graphs 5, 6, 7, and 8 give the sky and ground daylight factors for the same fenestration facing

Room No. 2 — Windows facing east.

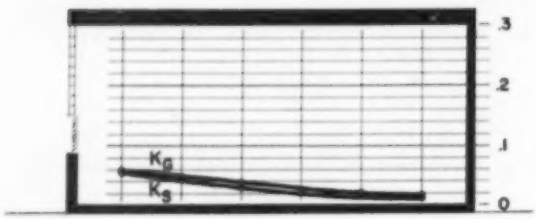


Graph 5.

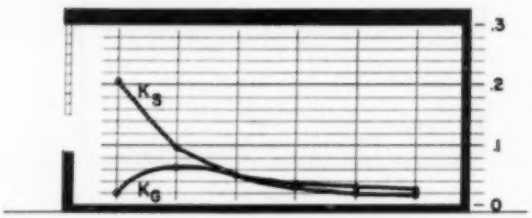


Graph 6.

Room No. 1 — Windows facing east.



Graph 7.



Graph 8.

east. Two sets of data for Equation 1 were obtained by making observations on a clear day and on an overcast day in the period from October 30 to November 4. The meters were Weston type illumination meters which had recently been calibrated against a standard lamp.

A study of the two sets of graphs shows that the sky and ground daylight factors are in close agreement and that the orientation of the fenestration, the kind of sky or the time of the year when the data are obtained do not produce variations in the sky and ground daylight factors which are larger than might be expected when experimental techniques are used.

Graph 6 shows a variation in the ground daylight factors which should be discussed. For plain glass windows of large area with no controls, the amount of illumination contributed by the ground at a given point, especially near the windows, is very small compared to that contributed by the sky. Under these conditions it is difficult to obtain sufficiently precise data to calculate accurately the ground daylight factor. For Graph 6, position 1, the value for K_g was a negative number. The only significance to be attached to this is that at point 1 the contribution of the illumination from the ground is a negligible factor. For other points in the room the contribution of the ground is sufficiently large to make the result more accurate. In the case represented by Graphs 5, 7, and 8 no difficulty is encountered in getting accurate results.

Conclusions

The first method provides a simple technique for making daylight surveys which requires only two illumination meters. The results are practically independent of sky conditions and are sufficiently precise for the comparison of different types of structures.

This method may be applied to multilateral fenestrations by covering all windows except the one being tested.

The second method provides a means of separating the illumination at a point into the components contributed by the ground and the sky. This method gives a means of evaluating the results when the designer has sought to make use of light from the surrounding terrain.

The second method is more difficult to apply, and for accurate results great care must be used in making the measurements, and the illumination meters must be checked for agreement.

The second method is applicable for the most part to single story structures, for as a rule, the ground adjacent to the building contributes little to the illumination on floors above the first story.

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1. Gunner Pleijel, Daylight Investigations, Statten Kommitte for Byggnadsforknin, No. 17, 1949.
2. Dr. R. A. Boyd: Daylighting in Classrooms, ILLUMINATING ENGINEERING, Vol. XLVII, pp. 21-25 (January 1952).
3. J. W. Griffith, O. F. Wenzler, E. W. Conover: Importance of Ground Reflection, ILLUMINATING ENGINEERING, Vol. XLVIII, pp. 35-38 (January 1953).

INSTALLATION AT RESIDENCE OF
MR. AND MRS. JAMES STANSELL, NASHVILLE, TENNESSEE.

Lighting an Entrance Hall

LIGHTING OBJECTIVE: To provide safe and comfortable illumination and extend a warm welcome to guests.

GENERAL INFORMATION: The foyer is 7 feet 4 inches by 16 feet 4 inches with a 9-foot ceiling. The front door and trim around glass panels are redwood. The supports for the plastic panels in ceiling and surrounding border are a dusty rose. The walls are rose beige (30% RF). The floor is brown and white marbelized tile (33% RF). There is a frosted glass partition dividing the foyer and the living room (not seen in the picture). The foyer lighting through this glass partition gives an interesting effect in the living room.

INSTALLATION: The luminous ceiling in the foyer is provided by the use of three 96-inch slimline fluorescent channels using deluxe warm white lamps mounted on 24-inch centers (see Fig. 2), 15 inches above the Rohm and Haas "Z" shape 24-inch plastic squares (see Fig. 3). Three lighting levels are provided in the foyer by combination switching; one switch controls the center lamp, and one the two outside lamps.

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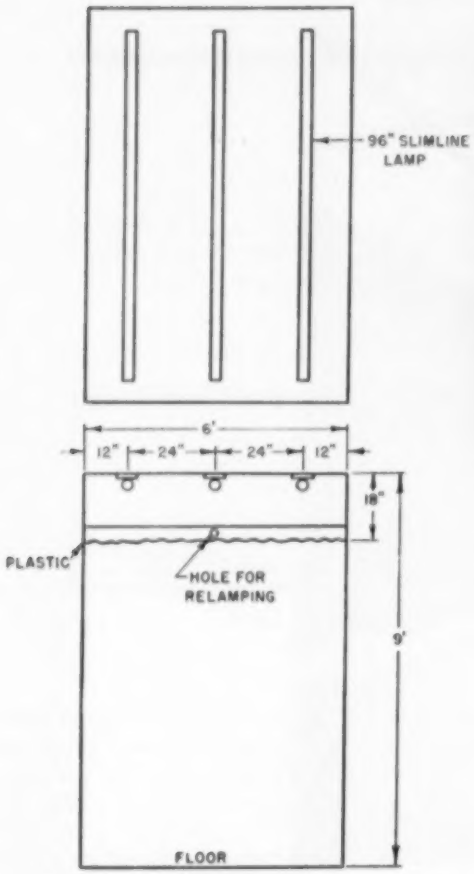

Figure 2. Detail of lamp arrangement.

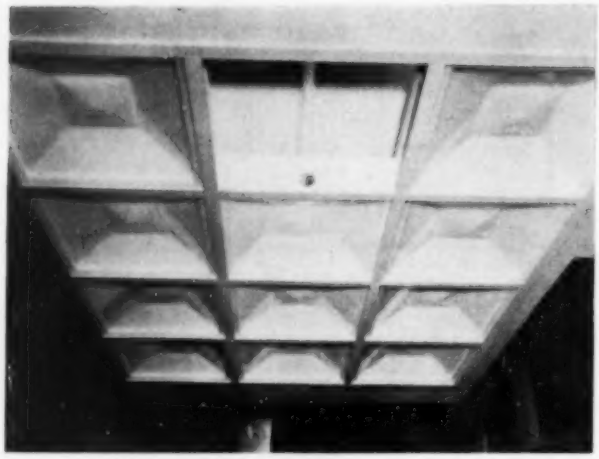

Figure 3. Close-up of ceiling, showing one panel removed.

Lighting an Entrance Hall (Continued)

Illumination and brightness readings are as follows:

General illumination	
All lamps operating	40 ft-c
Two outside lamps only	27 ft-c
Center lamp only	18 ft-c
Brightnesses	
All lamps operating	
Ceiling, normal viewing standing in front door	110 ft-L
Walls adjacent to ceiling (12 inches down)	11.5 ft-L
Walls, 5 feet from floor	10 ft-L
Floor	13 ft-L
Center lamp only	
Normal viewing seated in living room	80 ft-L

Electrical contractor: Stansell Electric Co., Nashville, Tenn.; architects: Hart, Freeland and Roberts, Nashville, Tenn.

Lighting data submitted by May Love Gale, Home Economist, Tennessee Valley Authority, Nashville, Tenn., as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

An Investigation of The Damage Hazard in Spectral Energy

By LAURENCE S. HARRISON

This paper is concerned with the deteriorating effects of spectral irradiation on materials and objects. It summarizes a recent report which was completed in December 1953 under the auspices of the Metropolitan Museum of Art, New York, for submission to other institutions in the museum field.

EVER since the introduction of commercial fluorescent lamps, public suspicions have existed regarding possible injurious radiation from them. These suspicions have decreased as acceptance of fluorescent lighting has increased, but, to those concerned, the hazards have never been too clearly defined. It might be justly stated that the art has been changing too fast to tie down lamp characteristics sufficiently to define them. It has been very difficult to get detailed information.

Whether or not basic design changes have reached a tableland only a prophet can say — but because the application of fluorescent lighting is extending to sensitive areas, such as museums and homes, where merchandise turnover cannot rescue material from over-exposure, clarification of this question has for some time appeared overdue.

Possible damage to museum collections in the use of fluorescent lamps was discussed at the meeting, in June of 1950, of the International Council of Museums in Stockholm, Sweden. Study of the subject was instituted and an interim report, dealing with the distribution of ultraviolet from standard lamps, was issued in November 1951. The Metropolitan Museum's investigation was authorized in June 1952, because of the urgent need for clarification in view of the extensive employment of fluorescent lighting in the reconstruction of its galleries then going forward.

Any evaluation of damage hazard inherent in fluorescent lamp radiation, if it is to mean anything, must be related to that of other commonly used light sources which constitute our visual environment and, therefore, our field of choice as to what may be done about it. Moreover, both solar radiation and the spectral transmittance of the glass tubing used for lamps cut off at approximately 290 mμ, limiting the field of comparison substantially to the near region of ultraviolet on through the visible spectrum.

The investigation* was consequently set up with four principal objectives in mind, viz.:

1. To determine the radiation hazards of the respective energy bands, both visible and invisible, which are produced by sources of natural and artificial light;
2. To determine the relative energy values of all such bands which are emitted from light sources as used in the Museum, viz, (a) sunlight, (b) clear sky light, (c) overcast sky light, (d) incandescent lamps, (e) fluorescent lamps;
3. To interpret the foregoing determinations in a manner useful for gallery lighting design;
4. To investigate practical means and methods for reducing such risks of damage as might be found to exist.

It quickly became apparent that the most recent and authoritative data, pertinent to objectives Nos. 1 and 2 were those resulting from the work of the National Bureau of Standards in preserving the original documents of the U. S. Constitution and Declaration of Independence. Accordingly, the cooperation of the Bureau was sought and generously given. The Bureau's report,[1] prepared by Dr. Deane B. Judd, together with supplementary information, checking and criticisms, were contributed and evaluated, with additional data developed in the Museum, in accordance with Objectives Nos. 3 and 4.

The record demonstrates certain general hypotheses which should be clearly understood:

(a) Both visible and invisible spectral energy tends to cause photochemical change;
(b) The shorter the wavelength the more photochemically potent irradiation will become;
(c) Photochemical change depends upon such energy being actually absorbed by irradiated molecules;
(d) Such absorbed energy must exceed a limit fixed by the absorption characteristics of an irradiated molecule;
(e) Photochemical change is retarded or accelerated by temperature or by the presence or absence of molecules, having chemical affinity with the absorbing molecule.

AUTHOR: Consulting Engineer, New York, N. Y.

*Acknowledgment is made of the objective criticisms and constructive assistance of Mr. Murray Pease, Curator of the Museum's Conservation Laboratory.

TABLE I (NBS).—Probable relative damage, D_λ, caused by unit irradiance as a function of wavelength compared to the luminous efficiency, y_λ, of radiant energy for the average normal eye (CIE standard observer).

Wavelength mμ	y_λ	D_λ	Wavelength mμ	y_λ	D_λ
300	0.0000	7.75	560	0.995	0.007
320	.0000	4.50	580	.870	.004
340	.0000	2.63	600	.631	.002
360	.0000	1.45	620	.381	.001
380	.0000	1.07	640	.175	.0005
400	.0004	.66	660	.061	.0000
420	.004	.37	680	.017	.0000
440	.023	.20	700	.0041	.0000
460	.060	.12	720	.0010	.0000
480	.139	.065	740	.0003	.0000
500	.323	.037	760	.0001	.0000
520	.710	.021	780	.0000	.0000
540	.954	.012			

Item (d), as summarized above, is shown by Dr. Judd to explain the conclusions given by Taylor and Pracejus[2] and by T. H. Morton[3] that fading of dyes is largely due to irradiation in the visible spectrum at or near the absorption maximum of the dyes, as well as due to ultraviolet.

Item (e) may also be taken to explain the vast variety of associations and environments which affect the fastness of dyes and pigments. For example, pigments of identical, chemical composition, when applied in an oil base on canvas, may be highly resistant to fading but, when applied as water color on paper, may be quick to fade. Further, any specific dye may be fast when applied to wool, but when applied to cotton may be highly fugitive.

Moreover, there are two distinct aspects of photochemical decomposition, each suggesting its own set of problems for further investigation. The first covers deterioration of mechanical properties, *i.e.*, loss of tearing strength, embrittlement and crumbling and the second relates to discoloration, either aspect reflecting one or some combination of the above-stated five conditions.

While the reports[4] of the National Bureau of Standards on the work of document preservation dealt with all possible hazards, that which dealt with the hazard of spectral irradiation disclosed the only available approach to objectives Nos. 1 and 2. The development of Relative Damage Factors as functions of wavelength by the Bureau has provided a significant contribution to which the subject investigation owes emphatic acknowledgment.

These factors were derived experimentally by study of the deterioration of cellulose products (low-grade paper). Obviously, many objects in museums and elsewhere have far greater resistance to deterioration than low-grade paper, as have the animal parchments of the Constitution and Declaration. It should also be noted that fading of colors was not an important objective of such study but in view of the five basic hypotheses given above, the validity of the Bureau's basis for relative damage factors could not be challenged. On the contrary, it would assure a safer margin for the exercise of judgment in view of the broadly uncertain resistance of materials to deterioration. These damage factors are given in Table I (NBS) in arbitrary units. They become negligible in the red end of the spectrum.

With these fundamental values at hand, the probable damage per footcandle (D/fc) of illumination from any light source is derived by Dr. Judd from the ratio of two sums:

$$D/fc = \sum_{760\ m\mu}^{300\ m\mu} H_\lambda D_\lambda \Delta\lambda \Big/ \sum_{760\ m\mu}^{300\ m\mu} H_\lambda \bar{y}_\lambda \Delta\lambda, \quad \text{where}$$

H_λ = The spectral irradiance of the light source;
D_λ = The Relative Damage Factor (Table I) of various wavelengths;
$\Delta\lambda = 20$ mμ;
$\bar{y}_\lambda$ = Luminosity at various wavelengths;
The sum in the denominator being the Illuminance in footcandles

These ratios (D/fc) have been calculated from the spectral distribution of irradiance (H_λ) of seven light sources, as required by objective No. 2. Such distribution is tabulated in Table II (NBS) and the ratios evaluate to the following Probable Rates of Damage per Footcandle for each *bare* light source.

Source	D/Fc	Per Cent
Zenith Sky Light	4.80	100.0
Overcast Sky Light	1.52	31.7
Sunlight	.790	16.5
Fluorescent Lamps —		
Cool White Deluxe	.554	11.5
Warm White Deluxe	.444	9.2
Daylight	.402	8.4
Incandescent Lamps	.136	2.8

Obviously, these light sources are rarely employed without interposing some sort of translucent filter. These normally include roof glass, window glass, ceiling glass, diffusing glass or plastic and distributing or light-controlling fixture glass. Studies of lighting glass were therefore made, and, in accordance with objective No. 4, the Bureau suggested that Corning Noviol-0 and Greenish Nultra be included in the studies. These are special ultraviolet filters which have high transmittance in the shortwave, visible spectrum. The Museum had already employed relatively costly, one-half inch thick, laminated X-ray glass, at appreciable sacrifice of blues, for the protection of its permanent

TABLE II (NBS).—Spectral distribution of irradiance, H_λ from the seven light sources studied. (Figures in parentheses are approximate color temperatures in degrees Kelvin.)

	Wave-length mμ	Incandescent lamp (2854K)	Daylight fluorescent *(6500K)	Warm-white deluxe fluorescent (2900K)	Cool-white Deluxe fluorescent (4300K)	Sun at 30° altitude (Air mass 2) (5300K)	Overcast Sky **(6400K)	Zenith Sky (11000K)
UV	300	0.04	0.05	3.1	4	8.4	7.1	36.6
	320	.55	.5	6.7	10	19.4	55.3	227.6
	340	1.18	.1	12.0	16	35.5	65.9	222.2
	360	2.10	6.2	17.0	32	42.2	67.0	183.5
	380	3.40	5.5	6.0	12	49.9	69.4	162.1
Visible	400	5.09	24.0	27.0	44	74.4	88.2	178.8
	420	7.26	21.0	6.0	30	96.3	103.8	185.4
	440	9.93	57.0	57.0	97	113.2	108.4	173.0
	460	13.10	31.5	7.0	46	121.7	115.3	166.8
	480	16.70	31.0	7.0	46	118.3	108.5	144.7
	500	20.70	28.0	13.0	49	121.5	106.5	130.4
	520	25.00	25.0	43.0	66	119.9	104.4	116.9
	540	29.70	34.5	79.0	100	119.8	100.7	106.2
	560	34.60	26.5	51.0	67	118.2	98.1	98.2
	580	39.50	35.0	77.0	88	116.8	95.3	91.1
	600	44.60	28.5	97.0	97	116.7	92.1	84.8
	620	49.60	19.0	95.0	95	116.5	88.7	78.7
	640	54.50	11.0	72.0	72	117.5	85.3	73.4
	660	59.50	6.0	45.0	47	116.6	81.9	68.5
	680	63.70	3.0	24.0	28	114.9	78.5	64.1
	700	68.50	1.4	12.0	14	110.8	74.7	59.9
	720	72.60	1.0	9.0	10	83.2	70.1	55.9
	740	76.40	.7	6.0	7	104.1	65.1	52.1
	760	80.00	.5	4.0	5	56.6	56.1	44.4

*Standard commercial rating 6500K, specimen tested evaluates to 8000K.
**Based on spe tral irradiance of sun outside earth's atmosphere through an average amount of water vapor assumed by Dr. Judd to be present in the atmosphere.

display of tapestries against daylight radiation at The Cloisters.

The glass ultraviolet filters suggested by the Bureau required, accordingly, a minimum sacrifice of good color rendition. They are highly satisfactory for use with incandescent lamps, but are too costly for the large openings of fluorescent fixtures. For the latter applications, the writer sought a solution in the field of plastics and Plexiglas Formula LPC 518K* was developed by Rohm & Haas Company and submitted to the Bureau. This plastic presents practically clear transparency to visible light while filtering out the highest percentage of ultraviolet of all those special u-v filters studied which give satisfactory transmittance over the whole visible spectrum, *i.e.* 390 mμ to 760 mμ.

The spectral internal transmittance of five filters is therefore given in Table III (NBS) with the same characteristics for X-Ray glass added for comparison.

It is only necessary then to modify the ratio, D/fc, for each of the seven bare light sources given above by the respective internal transmittances for each filter to obtain the Probable Damage Rates per footcandle of the various radiant flux densities to which materials may be subjected. These values are given in Table V (NBS).**

The next step was to associate (by multiplication) the damage rates (D/fc) with their coordinate levels of illumination experienced in the Museum. For artificially-lighted galleries, illumination was established, by design, at 30 footcandles horizontally, and 12 footcandles, plus spot or flood emphasis, vertically.

For daylighted galleries many variables had to

TABLE III (NBS).—Spectral internal transmittance of the six filters studied.

	Wave-length mμ	Kingsport water-white glass	Ordinary window glass	Corning Greenish Nultra Glass	Corning Noviol 0	Plexiglas LPC-518K	Pittsburgh Laminated X-Ray Lead
UV	300	0.048	0.000	0.00	0.000	0.000	0.000
	320	.557	.000	.00	.000	.000	.000
	340	.933	.380	.00	.000	.000	.000
	360	.986	.783	.06	.000	.001	.000
	380	1.000	.902	.34	.084	.028	.000
Visible	400	1.000	.946	.74	.44	.635	.031
	420	1.000	.967	.87	.69	.962	.218
	440	1.000	.978	.93	.81	.989	.478
	460	1.000	.978	.96	.90	.992	.675
	480	1.000	.978	.97	.93	.995	.798
	500	1.000	.989	.98	.96	.997	.870
	520	1.000	.989	.99	.98	.998	.903
	540	1.000	.989	1.00	.99	.999	.915
	560	1.000	.989	1.00	1.00	1.000	.922
	580	1.000	.978	1.00	1.00	1.000	.923
	600	1.000	.978	1.00	1.00	1.000	.922
	620	1.000	.967	1.00	1.00	1.000	.907
	640	1.000	.957	1.00	1.00	1.000	.895
	660	1.000	.946	1.00	1.00	1.000	.890
	680	1.000	.940	1.00	1.00	1.000	.884
	700	1.000	.935	1.00	1.00	1.000	.875
	720	1.000	.924	1.00	1.00	1.000	.869
	740	1.000	.913	1.00	1.00	1.000	.856
	760	1.000	.891	1.00	1.00	1.000	.843

*Internal Transmittance at 390 mμ is 0.003.
NOTE: If both Kingsport Water White Glass and Plexiglas LPC-518K are used together in a fluorescent fixture the combined transmittance will be the same as for the Plexiglas filter above.

*LPC 518K is a laboratory formula number; Rohm & Haas commercial designation is Plexiglas II UF.
**Table IV, given in the Museum's report, shows examples of the calculations made and is omitted here for brevity.

TABLE V (NBS).—Probable rate of damage per footcandle and approximate color temperature (degrees Kelvin) for 49 light sources expressed both in arbitrary units *D/fc* and in per cent of zenith sky (%).

Filter	Incandescent Lamp (2854K)		Daylight Fluorescent *(6500K)		Warm-White Deluxe Fluorescent (2900K)		Cool-White Deluxe Fluorescent (4300K)		Sun at 30° Altitude (Air mass 2) (5300K)		Overcast Sky (6400K)		Zenith Sky (11000K)	
	D/fc	%	D/fc	%	D/fc	%	D/fc	%	D/fc	%	D/fc	%	D/fc	%
None	0.136	2.8	0.402	8.4	0.444	9.2	0.554	11.5	0.790	16.5	1.52	31.7	4.80	100.0
Kingsport Water White	.128	2.7	.392	8.3	.332	6.9	.463	9.6	.619	12.9	1.19	24.8	3.38	70.4
Window Glass	.106	2.2	.362	7.5	.213	4.4	.294	6.1	.427	8.9	.682	14.0	1.58	32.9
Corning Greenish Nultra	.069	1.4	.262	5.5	.099	2.1	.163	3.4	.225	4.7	.299	6.2	0.544	11.3
Plexiglas LPC-518K**	.062	1.3	.245	5.1	.086	1.8	.147	3.1	.192	4.0	.243	5.1	0.407	8.5
Corning Noviol-O	.053	1.1	.197	4.1	.069	1.4	.119	2.5	.158	3.3	.199	4.1	0.334	7.0
Pittsburgh Laminated X-Ray	**		**		**		**		.079	1.6	.092	1.9	0.134	2.8

*Standard commercial rating, 6500K. See footnote TABLE II.
**LPC-518K filters cannot be used in incandescent lighting fixtures if temperature exceeds 180F. Plastic laminated X-Ray glass will take prolonged exposure to temperatures not exceeding 130F. Due to such operating temperature limits and its spectral color transmittance values, peaked at 580 m_μ, this filter was proposed only for screening UV from natural sunlight and daylight.

be resolved respecting sun, sky and overcast conditions. Extensive measurements of interior, daylight illumination were made by the Museum during the years 1950 and 1951. These were evaluated together with local (Central Park, N. Y. C.) meteorological data, resulting in the following annual, average, interior daylight illumination:

	Horiz. Ft-c	Vert. Ft-c
For Galleries without Sun Louvers	498	174
For Galleries with* Sun Louvers	169	59

The above tabulation covers both clear and overcast conditions in the proportion of 55.3 per cent of the possible local hours of sunshine (U. S. Weather Bureau) over the period of observation. The basis of determining the damage hazard from the three daylight sources, which produced the above interior illumination, was provided from published data[5] which indicated the following annual, average daylight illumination outside the Museum.

New York City	Clear Sky and Sunlight	6450 ft-c
New York City	Overcast Sky Light	1160 ft-c

These figures provide complete data on illumination levels with which to determine the actual degree of hazard existing in the Museum.

Multiplying *D/fc* by the footcandles of illumination applying to any particular condition expresses the Degree of Hazard in definite quantitative terms but to do so provides a series of values with little general significance. For example, the annual New York City average illumination from clear daylight is taken at 6450 ft-c of which 1280 ft-c is of sky light and 5170 ft-c is of sunlight. When these values are multiplied by their respective damage rates (*D/fc*), and added, we obtain a figure of 10,228 to express Degree of Hazard. This might be used as a basis of comparison with conditions in Central Park, New York City, but with nowhere else.

*When properly operated.

However, by selecting some average, standard value of illumination, reflecting common experience, which can be reduced to a unit basis, we can evolve a significant coefficient for any degree of hazard developed. Such standard value appears reasonable by taking 8000 ft-c of daylight, at 30 degrees of solar altitude,[5] consisting of 6900 ft-c of sunlight and 1100 ft-c of clear, zenith sky light. This reflects, as nearly as possible, the spectral distributions of irradiance representing average conditions in dust-free and smoke-free regions of the Temperate Zone which are taken by the National Bureau of Standards in Table II. This evaluates, by Table V, as follows:

6900 ft-c of Sunlight at .790 *D/fc* =	5451
1100 ft-c of Sky Light at 4.80 *D/fc* =	5280
Degree of Hazard =	10731

If we take the quantity, 10731, to equal 100 units of "exposure," then the ratio of any other evaluation to the base, 10731, will result in a Coefficient or Index of Exposure (IX) expressing the Degree of Hazard under standard conditions. Thus —

New York City, Clear Sky and Sun (6450 ft-c)
(10228/10731) × 100 = IX 95.5
New York City, Overcast (1160 ft-c)
(1763/10731) × 100 = IX 16.5
New York City, Annual Average
(95.5 × .553) + (16.5 × .447) = IX 60.19

The above described procedure results in Table VI showing the Index of Exposure for all significant conditions within the Museum, taking the effects of lighting glass into consideration and including the performance of available, protective ultraviolet filters.

The foregoing appears to define the hazard of spectral irradiation, per se, sufficiently to avoid extravagant speculation but, from the standpoint of practical control, there still remains a highly uncertain area to be further explored. The resistance of materials to deterioration from spectral energy

TABLE VI.—Probable Degree of Damage Hazard (Annual) from Light Sources in the Metropolitan Museum of Art. (Showing average illumination from source, ft-c and Index of Exposure, IX).

Condition and Location	ft-c	IX
Standard clear sky and sun	8000.	100.
N. Y. City clear air and sun	6450.	95.5
N. Y. City overcast	1160.	16.5
1. DAYLIGHT IN GALLERIES*:		
(a) Floor exhibits — without sun louvers	498	3.02
(b) Wall exhibits — without sun louvers	174	1.06
(c) Floor exhibits — with sun louvers**	169	1.03
(d) Wall exhibits — with sun louvers**	59	0.36

2. ARTIFICIAL LIGHT IN GALLERIES:

	INCANDESCENT (2854K)		FLUORESCENT: Daylight (6500K)		Warm Deluxe (2900K)		Cool Deluxe (4300K)	
Location & Special Filter If Any	ft-c	IX	ft-c	IX	ft-c	IX	ft-c	IX
Floor Exhibits:								
Bare	30	0.04	30	0.11	30	0.12	30	0.15
Water White Glass	30	0.04	30	0.11	30	0.09	30	0.13
Corning Noviol-0	30	0.01	—	—	—	—	—	—
Plexiglas LPC-518K	—	—	30	0.07	30	0.02	30	0.03
Wall Exhibits:								
Bare	12	0.02	12	0.04	12	0.05	12	0.06
Water White Glass	12	0.01	12	0.05	12	0.04	12	0.05
Corning Noviol-0	12	0.00	—	—	—	—	—	—
Plexiglas LPC-518K	—	—	12	0.03	12	0.01	12	0.01
Emphasis Spots:***								
Bare	60	0.08	—	—	—	—	—	—
Water White Glass	60	0.08	—	—	—	—	—	—
Corning Noviol-0	60	0.02	—	—	—	—	—	—
Case Lighting								
Bare	60	0.08	60	0.22	60	0.24	60	0.30
Window Glass	60	0.06	60	0.20	60	0.12	60	0.16
Water White Glass	60	0.08	60	0.22	60	0.18	60	0.26
Plexiglas LPC-518K	—	—	60	0.14	60	0.04	60	0.06

*Based on probable rate of damage per footcandle (D/fc), adjusted for transmittance through roof and ceiling glass, Clear Sky—1.56, Sun—0.421, Overcast Sky—0.672, in proportions as given.
**When properly operated.
***These values, both in ft-c and IX, should be added to those for general illumination whichever source is used for either floor or wall exhibits.

has not been quantitatively based in spite of the effort and years of investigation which have been devoted to the subject.

Given the degree of hazard under any specific conditions of light source and incident flux density (which now appears to be broadly predictable), the exposure-time required for observable damage is wholly a function of the resistance possessed by the irradiated material. Based on data derived by the Swedish Government's Testing Institute, from tests applicable to a special class of susceptible museum objects, the Metropolitan's report projects a purely hypothetical set of co-ordinate life-expectancies of objects on *continuous* exhibition. These range from six years on the walls of unprotected (louverless), daylighted galleries to over 600 years on the walls of artificially lighted galleries using 4300K fluorescent lamps and plastic ultraviolet filters, or for an indefinite duration for incandescent lamps equipped with specified glass ultraviolet filters.

Such projection, as stated in the report, is not to be relied on and is intended only to "find the range" of the problem. Without some such sampling, the broad uncertainties respecting the behavior of materials, under otherwise predictable and controlled exposure, would justify no other action but to keep susceptible objects of historical value under wraps for as long periods as possible.

The pioneer work of the National Bureau of Standards for the preservation of historical documents points the way, in the writer's opinion, along which future investigation might well proceed. Spectro-photometry and dyestuff chemistry may have done their parts. Perhaps the physiochemist should take over. Items (d) and (e) of the basic hypotheses, though differently worded by Dr. Judd, imply that a molecule often discriminates. Perhaps some associated molecule, or even an energy quantum, has catalytic properties?

In any event the work of the Bureau has made possible to museum people a clearer understanding of the hazards in natural and artificial light as well as the availability of practical measures for the better protection of their collections.

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A Rectangular Coordinate Photometer For Large-Area Luminaires

By JOHN A. LOSH

LAMP AND LUMINAIRE design have pushed us beyond the area in which classical, or "point source," photometrics is applicable.

The origins of photometry were based on the fact that the size of the source was small, so that the source, usually a candle, could be considered as a point source of light. After the invention of the incandescent lamp, because the size of the source was still small, classical photometry could still be used to give true results over the range of distances usually encountered in rooms.

Fluorescent lamps, on the other hand, because of their large size, cannot be considered point sources in ordinary rooms, despite the fact that present day photometry of fluorescent luminaires is based on the assumption that a fluorescent lamp is a point source of light. It is a common practice to design a photometer with a test distance of five times the maximum luminaire or source dimension. This dictates a photometric laboratory whose dimensions are in excess of 80 feet. Compromises are made whereby the dimensions need be only in excess of 40 feet.[1, 2]

Point source photometry presupposes an angular displacement and the secondary photometric concept of candlepower. If we ask ourselves, "Where is 35° from an overall ceiling?", or "Where is five times the maximum dimension from an overall ceiling?", we must realize that these questions have no answers; that point source photometry becomes inapplicable to large area luminaires. At least one attempt[3] has been made to extend point source photometry to include large area luminaires, such as louvered and luminous ceilings.

Photometry consists of measuring at a given point the light from all space. In order to determine light output from a luminaire it is necessary to make the light from the remainder of the space equal to zero. *This is the fundamental criterion of luminaire photometry.* Thus it is common practice to photometer a luminaire in a room painted black. It would also be possible and proper to photometer a luminaire in a country field on an overcast night, or in any number of other similar situations.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 14-17, 1953, New York, N. Y. AUTHOR: Smithcraft Lighting Div., A. L. Smith Iron Co., Chelsea, Mass.

Apart from this fundamental criterion of luminaire photometry, there are some allied criteria based on the method of photometry and in the mind of the photometrist. Thus there is no law of physics which requires us to use this antiquated point source photometry on luminaires that can by no strength of the imagination be considered point sources.

For purposes of calculation a system of photometry must be developed to accommodate these extensive luminaires. The purpose of this paper is to present a theoretically sound and practical method of photometry for such luminaires.

An important simplifying feature of small sources is the fact that the interflections between the room and the luminaire are small in effect, and can be neglected. With large sources the interflections become appreciable and an accounting of the effects must be made.[4] This fact alone is sufficient to disqualify the use of point source photometry.

Thus classical, or spherical coordinate, photometrics and its corollary the "Lumen Method" become inoperative for extensive luminaires, and origins must be found elsewhere. The Interflectance method provides the proper origin for the photometry.

Once the origin, or basis, of the photometry has been established, there are several practical considerations that a photometric laboratory must satisfy, of which a few are:

1) The laboratory must be large enough to accommodate the largest luminaire that is to be photometered in it.

2) The surfaces of the laboratory must be contiguous; they must form an envelope for the luminaire.

3) All surfaces of the laboratory must be finished with the lowest attainable reflectance to reduce interflections as much as possible.

4) The equipment must be selected to suit the method of photometry.

These considerations will be investigated at greater length below. This discussion applies to a particular photometer designed and built for the experiments, and is intended as a guide for other experiments.

In order to avoid interference with the measurements, the laboratory should be several feet larger

in its horizontal dimensions than the maximum size of the luminaire which is to be photometered in it. It is true that there is no limit to the size of ceiling lighting systems. The effects of the size on output can be accounted for analytically,[5] so that the size of the luminaire can be selected for convenience, and it should be large enough to be representative of all sizes.

Because we speak of light from room surfaces, it is only natural to measure light incident on room surfaces. Because the great percentages of our rooms are rectangular and not spherical, it follows that the photometer should be a "rectangular coordinate" photometer.

The great advantage of the rectangular coordinate photometer is that there is no minimum test distance associated with the photometer. The height should be of the same order of magnitude as the width; conversely, a height of eight to ten feet is best for ease of measurement, so the width of the photometer should be between six and sixteen feet.

The surfaces of the photometer should be rigid, and must be orthogonal to the plane of the shielding. Inasmuch as the garden-variety lightmeter is calibrated in lumens per square foot, readings of incident illumination should be made on each one-foot square. The photometer surfaces should for simplicity have a positive means for repetitive location of the lightmeter in its many locations. Also because of the square-foot basis, the dimensions of the photometer should be integral multiples of one foot.

The distinct classifications of Floor lighting, Wall lighting and Ceiling lighting unique to the Interflectance method replace the vague corresponding categories of the Lumen method: direct, horizontal and indirect. In all, there are twelve variables which enter into the overall photometry. They are the:

1) Room coefficient of the cavity.
2) Reflectance of the cavity.
3) Efficiency of the luminaire.
4) Flux distribution from the luminaire.
5) Total lamp lumens.
6) Reflectance of the shielding.
7) Transmittance of the shielding.
8) Room coefficient of the room to be lighted.
9) Wall reflectance of the room to be lighted.
10) Floor reflectance of the room to be lighted.
11) Apparent ceiling reflectance of the room to be lighted.
12) Tables of Interflectance.[6]

The selection of the proper instruments is simple, but important. A cosine-corrected lightmeter[7] is used to take readings of incident illumination on the room surfaces. The lightmeter is an absolute, not relative, meter. Thus to calculate the efficiency, the absolute lamp output must be known at any time. In order to know the lamp output under test, it is necessary to have a portable instrument which can give this information. Coradeschi and Innis[8] designed their "pharometer (reader of lumens)" which is remarkable in its simplicity. A meter of this type was used in the experiments. Briefly, it is an instrument which measures center lamp brightness. By prior measurement, this brightness can be converted to lamp output.*

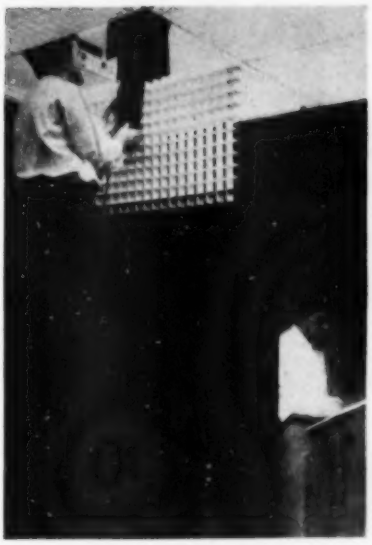


Figure 1. Applying the pharometer to a lamp to determine the lamp output. The cell is connected to a galvanometer. Calibration of the cell-galvanometer combination was done prior to these measurements.

In light of these considerations a photometer was designed and built for the purpose of obtaining photometric data on a ceiling lighting system. There follows a detailed description of the photometer, the results, and the application to interior lighting calculations.

The laboratory was a room 15 ft x 16 ft x 10 ft high designated as an office and showroom. In this area we installed a 12 ft x 12 ft section of ceiling lighting. This size was selected because the room coefficient of the cavity was about midway between the maximum and minimum limits.

Lamp constants were determined separately and recorded for a group of identified lamps. Of this group, eight 48-inch and 96-inch lamps were selected whose lumen outputs were in the smallest range. These lamps were installed selectively into the ceiling on 18-inch centers so that the illumination was substantially balanced throughout the room. Measured corrections were determined

*See Appendix A.

whereby it was necessary to take measurements in only one quadrant of the room. For the other three-quarters of the room, a black velvet-like material was hung or laid, so that the basic criterion of luminaire photometry was satisfied. Fig. 2 shows a portion of the photometer.

In order to facilitate measurements, stove-head screws were locked into the plywood walls, so that the head stood ⅛ inch away from the wall. A rectangular aluminum plate 11½ by 12 inches was made with four index holes 90° apart, and keyed to fit under the screw heads. To this was attached a 10-inch diameter aluminum plate to which the light-cells were attached, and which had an index pin. The assembly was as shown in Fig. 2b.

With a two-cell lightmeter, like the Weston No. 756, a careful positioning can be made so that complementary bands will scan the entire length and width of the one-foot square. It is believed that this procedure will lead to the least error in measuring the average illumination on each square.

The plywood walls of the photometer were exactly eight-feet high, so it was impossible to set the screws 12 inches apart vertically. So rather than use two sets of screws for each position, the vertical spacing was made as follows from the top down: 11½", 12", 12", 12", 12", 12", 12", 11½", making each screw common to two positions. The horizontal spacing was in all cases 12 inches. Thus no special construction was necessary to mount the screws. The locating plate was used as shown for all but the top and bottom rows; it was rotated 90° for use on these rows. The floor was marked off in one-foot squares so that the plate could be located quickly and positively.

Measurements

Because of the high loading it was necessary to allow eight hours warmup time for the luminaire. After eight hours, the pharometer was applied to each lamp and the lumen outputs calculated. Readings were taken on each one-foot square, and orderly records were kept. The surface area of the photometer dictated 132 readings. (See Fig. 3). The pharometer was again applied to the lamps and lumen outputs again computed. Although the variation was always small, averages of before and after outputs were used in the calculations.

Interpretation of Results

The black-room readings have to be converted into information usable by the designer. First the efficiency is computed:

Efficiency is defined as the quotient of luminaire output to lamp output. The sum of all 132 readings, divided by the calculated lamp output is the efficiency of the ceiling system of this size under test. Equations are available[4] whereby the efficiency of other sizes of areas (actually for other cavity room coefficients) can be calculated. If the calculated efficiencies are made relative to unity for the cavity coefficient under test, then the other calculated efficiencies become correction factors to be applied to the measured data.

There is no interflectance equivalent to the classical "zone." Since the derived data are measured in lumens, none should be expected. The partial distributions (*i.e.*, percentage incident in walls and floor) are a function of the room coefficient, a fact

Figure 2a. (left) A view of the ceiling luminaire and the photometer. Because of the specular reflections from the "flat" black paint (reflectance 0.04), it was necessary to cover all but the surface under measurement with an all-absorbing material.

Figure 2b (right) Another view of the photometer, with the test plate shown mounted on a wall. For measurements on louvers, four readings were taken at each station to reduce shadow error.

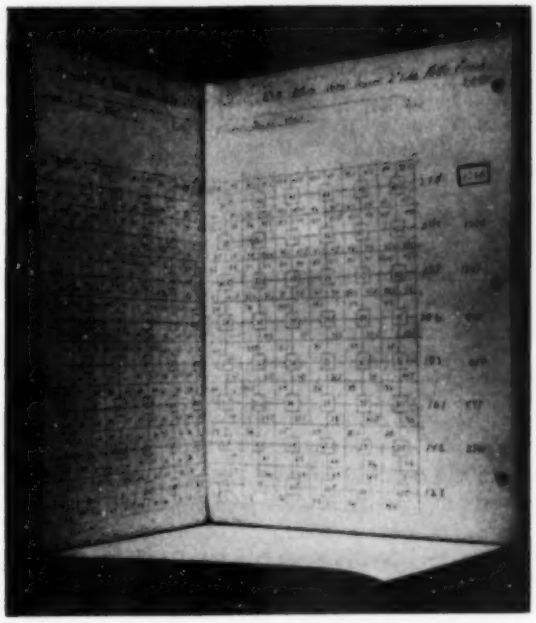


Figure 3. A reconstruction of the measurements. This construction is an exact reproduction of the illumination distribution as it existed in the test room.

which the lumen method ignores. Partial distributions are calculated by the process described below.

The specification of the room shape in the interflectance method is the room coefficient (domance). Its defining equation is

$$k_r = \frac{\text{wall area}}{\text{floor area}} \times 1/4$$

and for square rooms reduces to

$$k_r = \text{height/width}^*$$

The width of the room was 12 feet. For the test area, the height was eight feet. The room coefficient was therefore $k_r = .667$, and the total lumens incident on the floor were the sum of the values in each one-foot floor square. If the room were 7 feet high, the room coefficient would be $k_r = .583$, and because there was no change in the luminaire output, the total floor lumens would have been the sum of the readings on the floor and the bottom foot of wall. That is, the flux incident on the now nonexistent bottom foot of wall would be instead incident on the floor. Since only total incident flux is of importance, it is not necessary to measure specific floor illuminations for the 7-foot height. This procedure is also used for other room heights of 6 to 0 feet. The purpose is explained later.

It is common knowledge that shape and not size of a room specifies the light distribution. Therefore instead of decreasing the height we could have increased the width. But the same results would have obtained, and the mathematical method of changing the height is far simpler than the experimental method of changing the width.

The efficiency is defined by the familiar equation output/input.

The coefficient of utilization is defined by the equation

$$\frac{\text{Total lumens on working plane}}{\text{input}}$$

The quotient of coefficient of utilization to efficiency is the interflectance (called, in the Lumen method, the utilization factor).

The general equation for the interflectance is

$$f = f_1 F_1/F_D + f_2 F_2/F_D + f_3 F_3/F_D,$$

where f_1 = wall lighting interflectance
f_2 = ceiling lighting interflectance
f_3 = floor lighting interflectance
F_1/F_D = percentage of luminaire lumens incident on walls
F_2/F_D = percentage of luminaire lumens incident on ceiling
F_3/F_D = percentage of luminaire lumens incident on floor
F_D = total lumens emitted from luminaire $= F_1 + F_2 + F_3$.

In particular application of ceiling lighting systems, no light is incident on the ceiling, so that $F_2/F_D = 0$. The interflectance reduces to

$$f = f_1 F_1/F_D + f_3 F_3/F_D$$

The values of f_1 and f_3 are functions of the room coefficient and the surface reflectances. Values of F_1/F_D and F_3/F_D are functions of the room coefficient only.

Now the reason for calculating floor lumens as a function of room shape becomes evident. A further change in the last equation permits the calculation of only one of the F/F_D ratios:

$$f = f_1 + (f_3 - f_1)\frac{F_3^*}{F_D}$$

The calculated values of F_3/F_D are plotted against room coefficient. A typical distribution is shown in Fig. 4 for 45° cutoff louvers and for diffusing glass.

From the plot, values of F_3/F_D can be picked off at room coefficients the same as are used in the tables of interflectance.

All the equations must be examined to determine

*See Appendix B.

*See Appendix C.

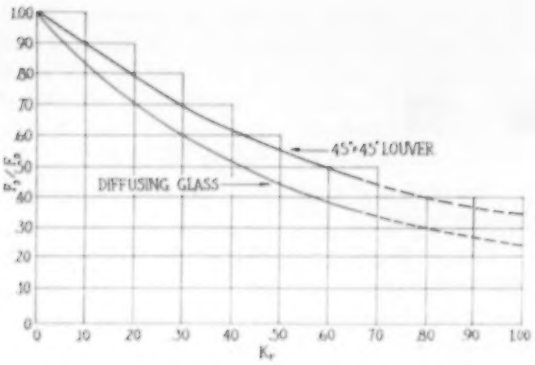


Figure 4. Percentage of total output of luminaire incident on floor (F_s/F_D) vs room coefficient (k_r). As expected, the louvers are more "concentrating" than the diffusing glass. Curves are extrapolated beyond $k_r = 0.667$.

the magnitude of the effects of the many variables. As the cavity room coefficient changes, the ceiling reflectance of the room to be lighted changes. For direct luminaires the effects of changing ceiling reflectance are generally small, so if lesser accuracy is desired, changes in ceiling reflectance can be neglected. This procedure is not endorsed.

Once the proper values are determined, calculations of interflectance can be made for all combinations of room coefficient and surface reflectances, according to the last equation, and the interflectance tables can be constructed.

It is standard procedure with "point source" luminaires to tabulate coefficient of utilization. Where the efficiency is constant it can be multiplied by the interflectance to obtain the coefficient of utilization. With ceiling lighting systems, however, the efficiency is a function of the room coefficient of the cavity; the interflectance is a function of the room coefficient of the room to be lighted. There is, unless assumed to the contrary, no correspondence between these two room coefficients. Therefore the constituents must be given separately. It is up to the designer to select the efficiency and the interflectance according to his specific information, and make the product himself in order to determine the coefficient of utilization for the room and ceiling combination. This coefficient of utilization is then entered into the basic equation for the calculation of illumination.

The procedure described must apply to any shielding media. It was followed for both 45° x 45° eggerate louvers and for diffusing glass. The results were checked against experimental information and were found to be in substantial agreement. Differences were well within the 10 per cent considered acceptable.

There is a conceptual problem with louvers which does not exist with other shielding media: various equations employ the reflectance and transmittance of the shielding. These characteristics are the "integrated" properties; they are not the reflectance and transmittance of the blade material.

Another theoretical problem arises with the use of louvers which does not seem to have an answer; nor does it seem to exist in fact. Simple solutions of the integral equations which form the basis of the interflectance method required the assumption that the room surfaces are perfectly diffusing. As a reflector a louver appears to be markedly nondiffuse. Because of this, some difference is to be expected between the measured and calculated data. No such difference appears to exist; whatever difference does exist cannot be attributed directly to this cause. The problem warrants further investigation.

Comparison was made between the calculated interflectances and the Harrison-Anderson utilization factors, both for the louvers and diffusing glass. Insofar as the two could be compared, no significant relation between the two could be found. No reason has been advanced which would indicate a relation between the two.

Summary

An attempt has been made to answer the need of a generalized system of photometries which is applicable to all luminaires. The described system applies expressly to large-area luminaires. The same general system will apply, with some necessary operational (not systemic) modifications, to small-area luminaires.

The photometric procedure is not presented as a final answer to a specific problem. It is hoped that the description may serve as a guide, in the absence of any accepted procedure, which does give results which agree with measurements. The description is also presented as a simple introduction to a different system of photometry, in the hope that it will stimulate a greater interest in an important and pressing problem.

Appendix A

There are two methods of converting this measured brightness into lamp lumens: 1) multiply the measured brightness by the published value of lamp output, and divide this product by the published value of brightness. There is certain error in this method because of the rough increments in which these values are given; 2) convert this measured brightness into candlepower, and then to lamp output, by several well-known formulas.

The first method is preferred for its simplicity, the second for its accuracy. Because in the experiment described accuracy was desired, the second method was used.

Basically this method is as outlined below:

$$F = (F/I)\, I$$
$$I = B_{av} A/\pi = B_{av} dL/\pi$$
$$F = (F/I)\, (dL/\pi)\, B_{av}$$

where F = lamp lumens
I = lamp 90° candlepower
B_{av} = lamp average brightness
A = projected area of lamp
= diameter, $d \times$ luminous length, L

The lumen/candlepower ratio may be measured for each lamp or assumed to be 9.25. The diameter and luminous length can be measured simply. The average brightness must be measured by a brightness meter, or as it is called in this case, the pharometer.

The defining equation of brightness is

$$B = \pi E_p/\omega$$

where ω = solid angle subtended by meter aperture at a point P
E_p = illumination at P from flux coming through the aperture.

The equation is used to calculate the average brightness of that part of the lamp seen through the aperture. The average of a series of measurements along the entire length of the lamp is the average lamp brightness.

Substituting this value of B into the equation

$$F = (F/I)\, (dl/\pi)\, (\pi E_{av}/\omega) = (F/I)\, (dL/\omega)\, E_{av}$$

If the pharometer has an aperture of length l, height d (= lamp diameter), and the receiving cell is set back a distance s from the plane of the aperture, then

$$\omega = dl/s^2 \quad (d << s, l << s) \quad \text{and}$$
$$F = (F/I)\, (Ls^2/l)\, E_{av}$$

Where E_{av} is the average of the measured illumination. It is simpler to relate the center-line illumination to the average, which can be done by prior measurement, so that during test only a single reading need be taken on a lamp with the pharometer. The final equation is then

$$F = (F/I)\, (E_{av}/E_{CL})\, (L_s^2/l)\, E_{CL}$$

The quantities F/I and E_{av}/E_{CL} are inherent properties of each lamp and can be predetermined. L, s and l are geometric properties which can also be determined. If L, s and l are in feet, then E should be in lumens per square foot. The product $(F/I \times E_{av}/E_{CL}\, Ls^2/l)$ can be made for each lamp, and lumped together as a single number for ease of computation. This constant, multiplied by the single measured illumination at the centerline, is the lamp flux for a lamp.

Appendix B

The defining equation for room coefficient is

$$k_r = \tfrac{1}{4}\, \frac{\text{wall area}}{\text{floor area}}$$

where the multiplier ¼ is used to normalize the room coefficient to unity for a cubical room.

For any rectangular room, the wall area is

$$2 \times \text{height} \times (\text{length} + \text{width}),$$

and the floor area is

$$\text{length} \times \text{width}.$$

Then,

$$k_r = \frac{2h\,(l+w)}{4wl} = \frac{h\,(l+w)}{2wl}.$$

For a square room, $l = w$, and

$$k_r = \frac{h\,(w+w)}{2w^2} = h/w \text{ as given.}$$

Appendix C

If the ceiling is of uniform brightness (perfectly diffusing) then the interflectance is that given for Type IIa lighting. Few if any transmitting materials are of uniform brightness, so it is not advisable to use the IIa interflectance, but rather the Ib and IIIb interflectances. The interflectance equation becomes

$$f = f_1 F_1/F_D + f_2 F_2/F_D$$

Since $F_2 = 0$, then $F_1 + F_2 = F_D$. Substituting $F_1 = F_D - F_2$ into this equation,

$$f = f_1 - f_1 F_2/F_D + f_2 F_2/F_D, \text{ or}$$
$$f = f_1 + (f_2 - f_1)\, F_2/F_D, \text{ also as given.}$$

References

1. Baumgartner, G. R.: "Automatic Recording Distribution Photometer and Simplified Calculation of Light Flux," Illuminating Engineering, Vol. XLIV, p. 253 (1949).

2. Horton, G. A.: "Modern Photometry of Fluorescent Luminaires," Illuminating Engineering, Vol. XLIV, p. 458 (1949). (References 1 and 2 are considered typical, though they represent only a small fraction of the literature on the subject.)

3. Potter, W. M., and Oetting, R. L.: "Design and Illumination Characteristics of Louver and Louverall Systems," Illuminating Engineering, Vol. XLIV, p. 16 and Vol. XLIV, p. 341 (1949).

4. Moon, Parry, and Spencer, D. E.: "Interflections in Coupled Enclosures," *Journal of the Franklin Institute*, Vol. 250, No. 2, p. 151 (1950).

5. Ibid., p. 167.

6. Moon, Parry, and Spencer, D. E.: "Light Distributions in Rooms," *Journal of the Franklin Institute*, Vol. 242, No. 2, p. 111 (1946).

7. The continued use of a non-cosine-corrected, non-color-corrected cell for illumination measurements no longer seems to be justified. Illumination exists independently from our ability to measure it; it has been our task to invent meters to measure physical quantities accurately. Now that cosine-correctors are available, they should and must be used exclusively for illumination measurements, if the measurements are to be credible.

8. Coradeschi, R. A. and Innis, L. E.: "An Application of the Interflection Theory to Commercial Practice," Illuminating Engineering, Vol. XLIII, p. 949 (1948).

DISCUSSION

Domina Eberle Spencer*: The paper presented by Mr. Losh represents a major step forward in the field of photometry. The other procedures of employing the interflection method that have been described in this session are merely stopgap approximations based on the inherently inadequate candlepower distribution. It is time for the illuminating engineer to recognize that 8-ft. fixtures and 100-ft. luminous ceilings are not point sources. The work of Coradeschi and Innis[1] and of Losh are the first outposts of truly modern photometry.

Mr. Losh has shown how pharos ratios for any type of lighting that covers the entire ceiling can be devised.

A single curve provides sufficient information to calculate all the pharos ratios. The general equation is

$$f = \alpha_w + f_1 \alpha_1 + f_3 \alpha_3$$

where

f = interflectance of room,

f_1 = interflectance for wall lighting, Type Ib,

*University of Connecticut, Storrs, Conn.

f_3 = interflectance for floor lighting, Type IIIb *without direct light to principal surface*,

$$a_w = \frac{\text{lumens to principal surface}}{\text{lumens from luminaire}},$$

$$a_1 = \frac{\text{lumens to walls}}{\text{lumens from luminaire}},$$

$$a_3 = \frac{\text{lumens to floor}}{\text{lumens from luminaire}}.$$

For a given domance k_r, and wall, ceiling, and floor reflectances ρ_1, ρ_2, and ρ_3, the values of f_1 and f_3 are read from the basic interflection tables.[2]

The pharos ratio for the floor a_3, is found in Figure 4 for k_r of the room. The pharos ratio for the wall is

$$a_1 = 1 - a_3.$$

The pharos ratio a_w, for principal surface at distance h' below the ceiling is found by reading the value from Fig. 4 at $(h'/h)\,k_r$.

Example: $k_r = 0.50$, $\rho_1 = 0.50$, $\rho_2 = 0.70$, $\rho_3 = 0.30$
$(h'/h) = \frac{3}{4}$.

From the interflection tables,[2]

$f_1 = 0.276$	$f_3 = 0.1026$.
Diffusing Glass	$a_1 = 0.56$
	$a_3 = 0.44$
	$a_w = 0.53$

$$f = 0.53 + (0.276)\,(0.56) + (0.1026)\,(0.44) = 0.73$$

Louvered Ceiling	$a_1 = 0.44$
	$a_3 = 0.56$
	$a_w = 0.63$

$$f = 0.63 + (0.276)\,(0.44) + (0.1026)\,(0.56) = 0.81$$

Without measurement of the pharos ratios, the illuminating engineer might have attempted to approximate both systems by a perfectly diffusing ceiling for which $f_2 = 0.69$. Thus, he would be 5 per cent low for a diffusing glass ceiling and 15 per cent low for a louvered ceiling. The 5 per cent discrepancy for the "diffusing glass" may be associated with the fact that such glass is by no means a perfectly diffusing surface.

If the approximate formula mentioned in Losh's paper (which assumes that the pharos to floor and to principal surface are the same) had been used, values of interflectance would be

$f = 0.64$ for diffusing glass,
and $f = 0.74$ for louvered ceiling,
errors of 12 per cent and 9 per cent respectively.

In passing, note that the above example does not show that louvered ceilings are more efficient than luminous ceilings. When the logance of the luminaire is also included, the coefficients of utilization will ordinarily be found to be greater for luminous ceilings than for louvered ceilings.

It is to be hoped that many other engineers will follow Mr. Losh in discarding point-source photometry and in employing new, basically correct methods of dealing with modern lighting fixtures.

1. Coradeschi, R. A. and Innis, L. E.: "An Application of the Interflection Theory to Commercial Practice," ILLUMINATING ENGINEERING, Vol. XLIII, p. 949 (November 1948).
2. Moon, Parry, and Spencer, D. E.: *Lighting Design*, Addison-Wesley Press, Cambridge, Mass., 1948, Tables 5.05 and 5.06.

R. D. BURNHAM*: The author has taken the first step in a much needed re-evaluation of classic photometry to cover large-area light sources. He is to be congratulated on devising a system requiring a minimum amount of equipment and space to achieve relatively accurate laboratory results with area luminaires which have been unwieldy in the most elaborate photometric laboratories.

It is pointed out in this paper that there seems to be no measurable difference when the luminous intensity deviates from Lamberts Law. I hope Mr. Losh will continue his investigation to determine how warped the distribution curve can be without affecting the photometric results.

One physical set-up is photometered. The data are then projected theoretically to cover larger and smaller rooms or rather, different k_r values. In expanding these data, there must be a proportional change in plenum efficiency, as well as the calculated change in the light utilization in varying room sizes. The error in neglecting to compensate for varying plenum efficiencies could be in the order of 10 or 15 per cent according to test results. It is not clear in the article whether or not this factor is taken into account.

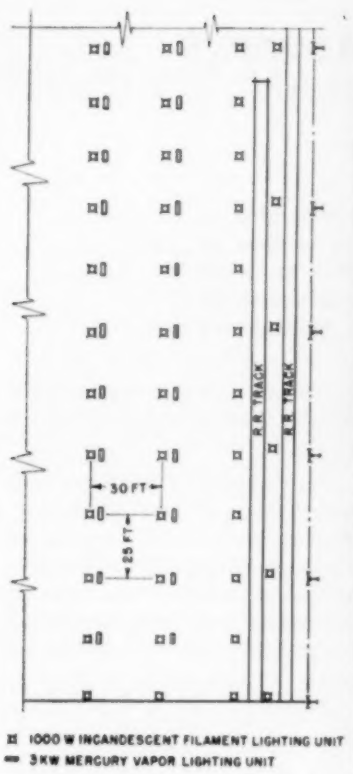
*F. W. Wakefield Brass Co., Vermilion, Ohio.

Edison's Fluorescent Lamp

The following article as printed in the 1904 edition of the Encyclopedia Britannica was submitted by C. E. Weitz, as of interest in the year of Light's Diamond Jubilee.

FLUORESCENT LAMP, an electric lamp invented by Thomas A. Edison in 1896. It has a bulb of glass, resembling that of the ordinary incandescent electric light, except that it is more circular, and that the wires enter at a greater distance apart. There is no platinum film to become incandescent, the light being obtained by coating the inside of the glass bulb with tungstate, against which the lines of force of the currents from the wires are directed, so that the molecules of air strike the tungstate, rebounding in all directions, and causing fluorescence. It is not necessary to maintain as perfect a vacuum as with the incandescent lamp and the whole globe glows with a white light that bears a strong resemblance in appearance to sunlight. The tungstate is attached to the glass by fusion. Other fluorescent metals besides tungstate may be used. No perceptible heat is developed by the light, which is in marked contrast to the incandescent lamp, which develops 95 per cent of heat and only 5 per cent of light. Professor Edison states that the Fluorescent lamp of 2-candle power will light a room as well as a 16-candle power incandescent lamp, though the photometer shows only about twice as great illuminating effect for lamps of the same candle power. It is also claimed that the new lamps will last much longer than the incandescent, since there is no filament to burn out.

ENCYCLOPAEDIA BRITANNICA 1904



INSTALLATION AT JONES AND LAUGHLIN STEEL CORPORATION, PITTSBURGH, PENNSYLVANIA.

High-Bay Industrial Lighting

LIGHTING OBJECTIVE: To illuminate the scarfing area of a steel mill to facilitate detection and removal of defects in billets and slabs.

GENERAL INFORMATION: In this scarfing area steel is inspected for surface imperfections such as seams, cracks and tears, which are then removed with acetylene torches, saws, etc. The area is approximately 350 by 120 feet. The floor is dirt.

INSTALLATION: Miller Company type PAM 3030 mercury vapor luminaires (3000-watt lamp) and Holophane type 691 AL high-bay incandescent filament units (1000-watt lamp) are spaced as shown above, 45 feet above the floor. The mercury vapor units are operated from the local electric utility's 60-cycle 440-volt 3-phase power supply. For continuity of service should the outside power service fail, the incandescent filament units are connected through auxiliary transformers to a 115-volt 25-cycle service supplied from the steel mill's power plant.

Average illumination in service is 45 foot-candles. All lighting equipment is out of the normal field of view.

Lighting data submitted by A. G. Caplan and E. M. Wenner, Duquesne Light Company, Pittsburgh as an illustration of good lighting practice and to aid in the design of similar installations.

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Questions and Answers on light sources

The I.E.S. Committee on Light Sources, under the chairmanship of H. F. Davidson, has prepared this discussion as an answer to a question on interchangeability of fluorescent lamps. Readers are invited to submit other questions of general interest on light sources to be considered for publication. Questions may be sent in care of Society Headquarters.

What are the differences between the 48-inch T-12 Preheat, Instant Start, and Rapid Start Bi-Pin lamps and what about their interchangeability?

Externally, these lamps are identical in appearance except for their marking. They are physically but *not* electrically interchangeable with the exception of the rapid start lamp which may be operated on a preheat type ballast.

Internally, these three lamp types differ only in electrode construction, each of which is designed for use with a specific ballast and circuit as follows:

1. *Preheat-Start.* This is the oldest (1939) and best known method of fluorescent lamp operation. During the starting cycle, a preheat current of 0.55-0.75 amperes is passed through the cathode coils by means of a special starter switch to bring them up to an adequate electron emitting temperature before the switch opens. After starting, the electron bombardment maintains the cathodes at a good electron emitting temperature.

2. *Instant Start.* In this method of lamp operation the ballast provides a relatively high open circuit voltage (450 volts) which is adequate to start the lamps instantly without the use of starter switches. Thus the lamps obviously start "cold cathode" but are quickly brought to proper operating temperature and maintained in that condition by the electron bombardment. Specially designed cathodes are required to resist properly the rigors of this method of starting. Safety regulations require that the primary circuit of the transformer be disconnected whenever a lamp is removed. The method used to accomplish this requires that the base pins of each lamp be short circuited inside the lamp base. Since the open circuit voltage of instant start ballasts is not sufficient for reliable starting under high humidity conditions if a moisture film is permitted to cover the lamp bulb, this situation is prevented by applying a water repellent coating to these bulbs. This coating, which is a silicone, prevents the formation of a continuous moisture film and therefore insures reliable starting under such adverse conditions.

3. *Rapid Start.* Rapid Start lamps have a third type of cathode construction. In Rapid Start operation, the cathodes are continuously heated by separate heater windings on the ballast. For reasons of quick and economical heating these cathodes are designed so that they attain an electron emitting temperature with only 0.38 amperes at 3.5 volts of heater power. These lamps require no starter switch; they glow as soon as power is applied and come up smoothly to full light output in about 2 seconds. The open circuit voltage of the ballast is a little over 200 volts for single lamp or lead-lag operation and just under 300 volts for series operation. Grounded metal reflectors are necessary for all Rapid Start circuits. Grounded electrical systems are usually required for single-lamp and lead-lag ballasts. Water-repellent coatings are applied to the lamps to assure reliable starting.

Interchangeability

Ballast	Lamp	Results
Preheat	Preheat	OK — Normal rated operation.
	Instant Start	NG — Won't start. Filament is short-circuited inside lamp base. Starter will keep trying until failure or disconnected.
	Rapid Start	OK — Satisfactory operation.
Instant Start	Preheat	NG — Will start. Very short life because primary current flows through one filament, causing early darkening and early failure.
	Instant Start	OK — Normal rated operation.
	Rapid Start	NG — Will start. Very short life because *high* primary current flows through one filament designed for *low* heating current.
Rapid Start	Preheat	NG — Not recommended. Might start with best grounding and high line voltage but doubtful and unreliable under usual field conditions.
	Instant Start	NG — Won't start. Short circuited filament across heater winding will overheat ballast and could cause burnout.
	Rapid Start	OK — Normal rated operation.

I.E.S. Guide for the

Electrical Measurements of Fluorescent Lamps

Prepared by the Committee on Testing Procedures for Illumination Characteristics of the Illuminating Engineering Society

Foreword

The following report replaces the 1948 guide of the same title. Experience gained in this field after the 1948 report was issued has resulted in the need for this revision, which lays special emphasis on the features most responsible for variations in performance.

This guide was presented at the International Electro-technical Commission held in Opatija, Yugoslavia in June 1953 with favorable response.

Subcommittee for Revision of I.E.S. Guide for Electrical Measurements of Fluorescent Lamps

Arthur W. Weeks, *Chairman*

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Rudolph Hultgren — W. F. Little
Leslie Innis — J. H. Park
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W. G. Hill — B. H. Schultz
A. W. Krawcek — R. P. Teele
A. W. Weeks

1. General

(a) This guide describes the procedure to be followed and the precautions to be observed in measuring the electrical characteristics of fluorescent lamps on alternating current circuits. These methods are applicable both to hot cathode lamps having self-heated cathodes and to cold cathode lamps. Hot cathode lamps having externally heated cathodes (such as the rapid start lamps) present additional measurement problems which are not covered by this guide.

(b) It is the purpose of this guide to outline methods of measurement which will make it possible to obtain reproducible and basically accurate measurements of fluorescent lamps.

2. Power Supply Characteristics

2.1—*Waveshape*—The a-c power supply shall have a voltage waveshape such that the rms summation of the harmonic components shall not exceed three per cent of the fundamental.

2.2—*Voltage Regulation*—The line voltage shall be as steady and as free from sudden changes as possible. For best results the voltage should be regulated to within ±0.1 per cent. If adequate automatic regulation is not available, constant checking and readjustment are essential if accurate measurements of lamp characteristics are to be obtained.

Note: If the static type of voltage stabilizer is used, it is particularly important to check the waveshape to see that it meets the specification given above in 2.1, Waveshape.

3. Ambient Conditions

Certain of the electrical characteristics and the light output of the fluorescent lamp probably are more sensitive to variations in ambient temperature or air movement than are the usual means of determining or controlling room air conditions. Means of exactly specifying the desired ambient test conditions have not yet been developed. Pending further investigation of ways and means of both specifying and controlling the necessary ambient conditions to provide reproducible measurements, the following are offered for use.

3.1—*Temperature*—The room in which lamp electrical measurements are being taken should be maintained at 80F(±1F). This temperature should be measured at a point not more than five feet from the lamp and at the same height as the lamp. If the ambient temperature deviates from 80F by more than one degree, it should be so stated in the test report. If temperature corrections are applied, the correction factor should be stated in the report.

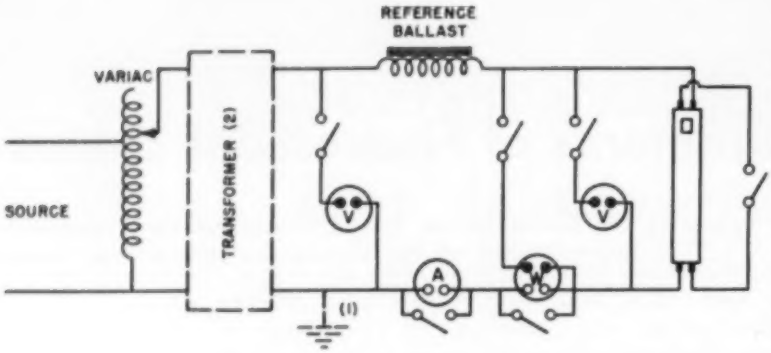
3.2—*Freedom from Drafts*—(a) The presence of drafts on the surface of a lamp under test will substantially alter the electrical and light output values. Slight drafts which might easily escape normal observation can cause important changes in the measured values. When electrical measurements of fluorescent lamps are being made, extreme caution must be exercised to reduce air movement to the lowest possible minimum if reproducible or accurate results are to be obtained.

(b) To minimize the effect of air circulation, lamps should be operated in a horizontal position when measurements are being taken. Lamps must not, however, be operated in small enclosures where the bulb wall temperature of the lamp might be increased above normal.

4. Ballasts

(a) When the electrical characteristics of a fluorescent lamp are being measured, the lamp should be operating in conjunction with a Reference Ballast of the appropriate rating. The use of a ballast having different characteristics (even though of the same impedance) can materially alter the electrical values of the lamps. The general characteristics of Reference Ballasts are described in the proposed

Approved by the Council of the Illuminating Engineering Society, June 1953.



(1) THIS SIDE OF CIRCUIT SHOULD BE THE ONE CONNECTED TO GROUND IF A GROUNDED SUPPLY SYSTEM IS USED.

(2) IT MAY BE NECESSARY TO INSERT A TRANSFORMER AT THIS POINT IN ORDER TO OBTAIN THE OPEN CIRCUIT VOLTAGE REQUIRED BY THE REFERENCE BALLAST FOR CERTAIN SIZES OF LAMPS. EITHER AN AUTOTRANSFORMER OR A DOUBLE WOUND TRANSFORMER MAY BE USED.

Figure 1. Measurement circuit for fluorescent lamps.

American Standard Specification for Fluorescent Lamp Reference Ballasts, C82.3. This standard also gives the proper impedance value for the Reference Ballasts corresponding to each of the lamp sizes for which lamp standards have been prepared.

(b) If electrical readings are to be taken on a lamp of a size for which no standard exists, the ballast used should be one complying with the general requirements of C82.3. The impedance of the ballast should be such that the supply voltage will, for preheat-start lamps, be approximately twice the lamp voltage and for instant-start lamps, three to three and one-half times the lamp voltage.

(c) For special purposes it may occasionally be desirable to determine the electrical characteristics of lamps when they are operated by other than Reference Ballasts. Where this is done, it must be remembered that such results are meaningful only for the particular ballast and circuit with which they were obtained. Such results are not directly comparable with data taken on a Reference Ballast.

5. Circuits

(a) The operating circuit of a fluorescent lamp is shown in the diagram of Fig. 1. The Reference Ballasts used for lamp measurement are of the series-reactor type and do not include a step-up transformer. In many cases a separate step-up transformer may be needed to provide the line voltage required by the Reference Ballast.

(b) The diagram shows the method of connecting instruments in the circuit. The voltmeter and the potential element of the wattmeter are connected on the lamp side of the current measuring instruments. Switches should be provided so that each instrument can be removed from the circuit when it is not being read. These switches should have low resistance and should be well maintained to preserve this property. If knife switches are used, a by-pass lead at the hinged end of each switch is recommended.

(c) Reference Ballasts may be set up either with or without the impedance of the ammeter and wattmeter current coil included in the measured ballast characteristics. Either procedure is satisfactory, but it is important that instrument corrections be determined for the particular method being used (see Section 9). If the ammeter and wattmeter current coil are included in the ballast impedance, these instrument coils *must* be left in the circuit at all times.

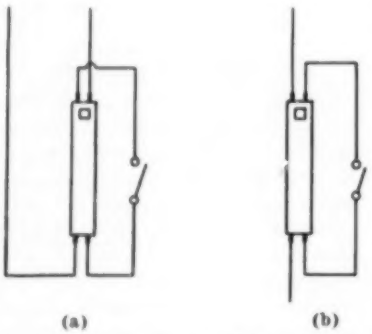


Figure 2. (a) Crossover and (b) parallel lamp connections.

(d) If the starting switch for a preheat-start lamp is normally shunted by a capacitor, this capacitor should be disconnected before readings of lamp characteristics are taken.

(e) The diagram as drawn shows a preheat-start lamp and its attendant starting circuit. The connections for an instant-start type of lamp are, of course, identical except for the omission of this starting circuit.

6. Lamp Connections

6.1—*Preheat-Start Lamps*— (a) Hot cathode bipin lamps are provided with two contact pins on each end of the lamp. One pin at each end is connected to the operating circuit and the remaining two pins are connected to the starter circuit. For consistent results, each lamp should always be operated with the same two pins connected to the operating circuit. This includes not only the operation of the lamp while measurements are being taken but also all other periods of operation prior to the time of measurement.

(b) One pin at each end of the lamp should be marked to indicate the operating circuit. The cross-over scheme is recommended as a standard procedure, but the parallel system, if consistently followed, will give equally satisfactory results. Fig. 2 shows both schemes of connections.

6.2—*Instant-Start Lamps*—No marking is needed for instant-start bipin lamps or single pin lamps.

7. Lamp Stabilization

(a) Before any measurements are taken the lamp should first be burned long enough to attain stabilization and temperature equilibrium. A period of 15 minutes' continuous burning usually is sufficient to accomplish this but it is better to rely on periodic checks of lamp voltage rather than merely the elapsed time. When the lamp voltage stops drifting downward, the lamp has then reached equilibrium.

(b) If lamps are warmed-up on one ballast and then transferred to a different ballast for measurement, an additional period of burning in the measurement circuit is usually necessary to bring the lamp to equilibrium. The length of the additional burning

period can be kept to a minimum by transferring the lamp without extinguishing it and also by using Reference Ballasts in the warm-up circuit. If the lamp *is* extinguished during the transfer, or if the warm-up ballast does not match the measurement ballast, the additional burning time in the measurement circuit will be longer, possibly as long as five or ten minutes.

(c) No lamp which shows swirling or other abnormal behavior may be considered to be stabilized for measurement purposes.

8. Instruments

8.1—*Accuracy* — Instruments should be selected which have a guaranteed accuracy commensurate with the requirements of the test. Scale calibration is essential to obtain reasonable accuracy of results.

8.2—*Impedance Limitations* — **(a)** High potential-circuit impedance and low current-circuit impedance are desirable to reduce the disturbance of the circuit caused by the presence of the instruments.

(b) Instruments connected in parallel with the lamp should never draw more than three per cent of the rated lamp current.

(c) Instruments connected in series with the lamp should have an impedance such that the voltage does not exceed two per cent of the rated lamp voltage.

(d) Potential-circuit amplifiers having high input impedance and an accurately controlled gain may be inserted to avoid corrections due to disturbance of the lamp circuit. The output of such amplifiers must faithfully reproduce the input voltage with respect to rms value (or a multiple thereof), waveshape and phase relation.

8.3—*RMS Measurements*—The voltage across a fluorescent lamp has a distorted waveshape which departs considerably from a true sine wave. Therefore, the instruments used in lamp circuits must be of a type whose deflection depends upon rms values. Instruments whose scales are calibrated in rms values but whose deflections depend upon average or peak values should *not* be used.

8.4—*General Characteristics of a-c Instruments* — A discussion of the characteristics of the following types of instruments may be helpful.

8.4.1—*Electrodynamic* — Electrodynamic instruments give a deflection which is proportional to rms values and they can be designed for accurate measurements over a moderate range of frequency. Most electrodynamic instruments have fairly low potential circuit and high current circuit impedances, but designs are available whose characteristics are within allowable limits for fluorescent lamp circuits. Most electrodynamic instruments can be calibrated by means of reversed readings on direct current and they maintain calibration well. It should be noted, however, that in certain varieties of these instruments, the hysteresis loss is high enough so that direct current calibration alone may not always be reliable. In such cases the instruments must be calibrated on alternating current.

8.4.2—*Electrostatic* — In most designs the deflection of electrostatic instruments is proportional to rms values. These instruments are accurate over a wide range of frequency and their potential circuit impedances are very high. Their deflection torque is very low and because of this they require a fairly long time to reach a steady deflection. They are also subject to zero shift.

8.4.3—*Iron Vane* — Iron-vane instruments give a deflection which is proportional to rms values and they can be designed for use over a moderate range of frequency. As in electrodynamic types, a design whose impedances are within the allowable limits must be chosen. Theoretically these instruments should be calibrated only on alternating current because hysteresis occurs to some degree in the vane. Practically, however, the hysteresis in modern instruments is often so small that direct current calibration can be used with satisfactory results.

8.4.4—*Thermal* — The deflection of thermal instruments is proportional to rms values. These instruments are accurate over a wide range of frequency and their potential circuit and current circuit impedances are usually within required limits. However, their calibration depends rather critically upon instrument temperature, the change being from 0.1 to 0.3 per cent per degree Centigrade. Therefore, it is very important that the instrument temperature be maintained uniform and constant (no sources of heat located near the instrument) and that the instrument be calibrated at the same temperature at which it is used.

8.4.5—*Rectifier*—The deflection of rectifier instruments is proportional to average values. These instruments, therefore, should not be used to measure the rms value of a distorted wave.

8.4.6—*Electronic*—In most designs the deflection of electronic instruments depends upon peak or average values. Such instruments should not be used for rms measurements of a distorted wave. However, some designs of electronic instruments may be suitable for rms measurements. An investigation of their accuracy in fluorescent lamp circuits should be made before such instruments are used.

9. Corrections to Compensate for the Presence of Instruments in the Lamp Circuit

9.1—*General*—(a) In measuring electrical values in fluorescent lamp circuits it is usually necessary to take into account the change in the circuit caused by the presence of the instrument. In determining the required corrections the basic method to be used is the "restoration-of-light" method in which a suitable photoelectric cell is used to measure lamp brightness. The output of the cell may be read on a galvanometer, microammeter or other suitable indicating device having a sensitivity comparable to the electrical instruments used. The cell should be so located that it sees the central portion of the lamp and it should be baffled to prevent its being influenced by extraneous room light. The procedure is as follows:

1. Set the proper rated line voltage across the lamp and Reference Ballast.
2. Note the lamp brightness as indicated by the photoelectric cell reading.
3. Insert the instrument (ammeter, voltmeter, or wattmeter) and with line voltage held constant, observe the instrument indication.
4. Readjust the line voltage until the output of the photoelectric cell is the same as before the instrument was inserted.
5. Record the reading of the instrument under this new condition. Within very close limits, this value will be the same as would have been obtained at rated line voltage if the instrument did not alter the lamp circuit.

6. Remove the instrument from the circuit and recheck steps (1) and (2). The photocell indication should agree with that originally obtained.

7. The difference between the instrument indication recorded in (5) and that recorded in (3), may be used as an instrument correction to be added to (or subtracted from) observations made when holding rated line voltage. This correction, of course, applies only for that particular instrument when used with that size of lamp.

(b) It should be noted that the reading for only one instrument at a time can be obtained by the above procedure. Also, instrument scale corrections must still be applied and for a wattmeter the power taken by its potential circuit (E^2/R) must be subtracted from the correction obtained.

(c) The exact procedure to be followed also depends upon whether the instrument current coils are or are not included in the Reference Ballast impedance. The procedure is somewhat different for each of the three instruments in the lamp circuit as outlined in the following paragraphs.

9.2—*Correction for Lamp Ammeter Reading*—(a) If the current coils have been included in the measured impedance of the Reference Ballast, no correction is needed for the presence of this instrument (*i.e.*, the restoration-of-light method should not be used), and the ammeter *must* be left in the circuit at all times.

(b) If the current coils have *not* been included in the Reference Ballast impedance, the ammeter correction should be obtained by the restoration-of-light method. The ammeter should *not* be left in the circuit while readings of other instruments are being taken.

9.3—*Correction for Lamp Voltmeter Reading*—Regardless of which procedure is followed for the current coils, the correction for the voltmeter reading is obtained by using the restoration-of-light method. The voltmeter should *not* be left in the circuit while readings of other instruments are being taken.

9.4—*Correction of Wattmeter Reading*—(a) If the current coils have been included in the measured Reference Ballast impedance the wattmeter current coil must be left in the circuit at all times and no correction need be made for the presence of this coil. The correction for the presence of the potential coil may be obtained by using the restoration-of-light method *and then* subtracting the power in the potential circuit (E^2/R). It will sometimes be found that the increase in watts when the lamp brightness is restored is very nearly equal to the decrease when E^2/R is subtracted. When this condition prevails it is then possible in routine work to omit both corrections and use the wattmeter readings directly. (An instrument scale correction, of course, must still be made.)

(b) If the current coils have not been included in the Reference Ballast impedance, the correction for both the current and potential coils may be determined at the same time by the restoration-of-light method. The power in the potential coil (E^2/R) must be subtracted from the reading obtained.

Industrial Lighting for Easy Maintenance

The management of the Acme Tank & Welding Division of United Tool & Die Co., in Hartford, wanted an abundance of light in their new shop with a fixture easy to keep clean without removing the lamps to do the cleaning. The area, which has a smoky and dirty atmosphere from the welding of steel tanks, is 120 x 38 feet with a 15-foot ceiling.

Thirty-four totally enclosed luminaires, each with two 96-inch slimline lamps, have ribbed glass bottoms which lift out for washing. The units are mounted in three rows on 10-foot centers. Illumination level after five months' operation without cleaning was 20 footcandles.

The floor is of unpainted concrete, and walls and ceiling are sheet steel with a coating of asbestos to help reflect the outside heat, and at the same time helping to reflect the light in the shop.

This installation won second prize for Harold R. Young, Litecontrol Corp., in the Connecticut Section's 1953 contest for My Most Interesting Lighting Job. T. J. Martin Electric Co. were contractors.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Dr. Erwin F. Lowry Awarded I.E.S. Gold Medal

In recognition of his many contributions to improved fluorescent light sources, the I.E.S. Council has unanimously approved the selection, by the Gold Medal Award Committee, of Dr. Erwin Foster Lowry as recipient of the I.E.S. Gold Medal. Highest honor in illumination, the I.E.S. Gold Medal is awarded to give recognition to meritorious achievement which has conspicuously furthered the profession, art or knowledge of illuminating engineering.

This is the first time a physicist engaged in light source research has been chosen to receive the Society's highest award. Presentation of the Medal and accompanying citation will be made by President Manwaring at the National Technical Conference in Atlantic City the week of September 13.

From Dr. Lowry's research there have emerged nearly thirty patents, almost all of which are related to gaseous discharge devices, especially cathodes. Most of his contributions to the art and science of lighting are found in the development of the fluorescent lamp.

Prior to his work on light sources he was engaged in radio tube research. From the early days of the radio industry, platinum was used in radio tube cathodes because it was the only metal known at the time that would not oxidize during tube operation. Lowry's brilliant researches on alloys proved that other metals not only could be used but that they would make better cathodes. From his discoveries came the use of nickel alloys now standard for radio tubes. Later the use of tungsten for certain types of cathodes followed as a logical result.

For the past twenty-five years Dr. Lowry has devoted his efforts to the specialized problems involved in the design and development of cathodes for gas filled tubes. Several new cathodes were found but, from the standpoint of fluorescent lamps, his most important work was his investigation of methods of protecting oxide cathodes from the injurious effect of ion bombardment.

Dr. E. F. Lowry
I.E.S. Gold Medallist

In the sixteen years since fluorescent lighting came into commercial use, fluorescent lamps have made greater gains in improved characteristics than any other light source, many of which can be attributed to the work of Lowry and the group he directed. Lamp life was increased from something less than 4000 hours to something better than 7500 hours through the use of zirconium oxide as a cathode material. Early failures were reduced and group replacement of fluorescent lamps became more practical. Other developments have greatly improved maintained light output. Dr. Lowry was also one of the pioneers in the development of fluorescent lamps and circuits designed for starterless operation; he introduced a lamp of this type in 1939.

In the field of phosphors Lowry initiated and directed research that has resulted in improved color uniformity, greater light output and through phosphor stability, in large gains in lumen maintenance.

Of importance both in the United States and abroad has been the series of papers, principally before the Illuminating Engineering Society, in which Lowry disclosed research data to correlate the electrical and light characteristics of fluorescent lamps. This series, which constitutes the basic data on fluorescent lamps, has made it possible to design fluorescent lamps to fairly rigorous specifications.

Dr. Lowry initiated and directed the research which led to the development of the electro-luminescent lamp as a practical device; and has presented several papers on this investigation both before I.E.S. and other scientific and engineering bodies.

A Fellow of I.E.S. (1950), Dr. Lowry has been active in Society work having been chairman of the Light Source Committee and the Committee on Fellows. He has presented numerous papers before the Society and other technical bodies and has written many articles. In addition to his I.E.S. activities, Lowry is a member-at-large of the United States National Committee, C.I.E., a member of the American Physical Society and of the Electrochemical Society where he has taken an active part in the Luminescence Section of the Electronics Division, of which he is a past chairman.

Born in Ridgeway, Michigan, in 1891, he received his bachelor's and master's degrees from Ohio Wesleyan University and his doctor's degree from Ohio State University. He was a member of the faculty of Ohio Wesleyan, Pittsburgh and Ohio State.

After receiving his doctor's degree in 1923 Lowry joined Armstrong Cork Company as a research engineer. Then until 1936 he was in charge of research and development of oxide cathodes for Westinghouse Electric & Manufacturing Company. For three years he was director of research for Continental Electric Company where he developed a line of rectifiers and thyratrons. The following year he was engaged in the development of fluorescent lamps for Flexolite Company where he was director of research.

Since 1940 Dr. Lowry has been associated with the Lighting Division of Sylvania Electric Products Inc. where he is now manager of the Lighting Engineering Laboratories.

Council Meets in New Orleans

Summary of Action Taken

The success of last year's "away from headquarters" Council meeting (in Dallas, Texas last April) led to a similar southern meeting in New Orleans April 10. Many regular Council members also attended the Southern Regional Conference which was held in New Orelans the two days previous, and the Region's officers and other Southern members had an opportunity to sit in on this important Society event. Present at the Council, held at the Roosevelt Hotel, New Orleans were: President A. Homer Manwaring, Past President S. G. Hibben and W. A. Feuillan, Jr. proxy for Past President E. M. Strong; Hutson Colcox proxy for Vice-President D. M. Jones and J. M. Guillory proxy for Vice-President R. F. Hartenstein; General Secretary M. N. Waterman; Treasurer K. M. Reid; Directors W. A. Stannard, J. F. Whitehead, Jr., John F. Morton proxy for F. C. Winkler, R. C. Paslay proxy for C. C. Shotwell, Harold L. Salaun proxy for J. S. Schuchert, Arthur A. Levy proxy for G. W. Beals; Regional Vice-Presidents M. J. Myers, Jr., Glenn E. Park, George J. Taylor, Jacob M. Gensburger proxy for C. J. Berry, Theodore C. Lauck proxy for G. B. Buck II, Harry T. Bailey, Jr. proxy for L. A. Hobbs; Executive Secretary A. D. Hinckley; Technical Director C. L. Crouch; Editor Ruby Redford; Advertising and Promotion Manager C. E. Ellis, and S. C. Berdon, W. W. Booth, J. D. Mitchell, Jr., R. L. O'Donovan, J. D. Poage, T. C. Sargent, G. J. Segel, Gordon Wells, C. W. Whitmore, G. E. Wilkinson and S. B. Williams.

Council's approval of the Executive Committee's recommendations as covered by the Minutes of their March 11 meeting resulted in the following action:

Carter Lewis was appointed to Vice-President Midwestern Region until September 30, 1954, filling the vacancy left by the resignation of C. B. Pederson (IE March, p. 20A).

The matter of new duties and responsibilities proposed for Directors of I.E.S. was referred for study to the Advisory Board on Committee Personnel.

Action to develop and maintain contact with the Engineers Joint Council and other engineering societies regarding discussions on Unity of Engineering Profession.

Appointment of a Society representative to review, together with a NEMA representative, text of the Manual underway for the NEMA certification program.

Membership

The General Board of Examiners recommended for approval by Council the election of 19 Members and the transfer to Member grade of three Associates. They further reported the election of 86 Associate Members and three Students. Following action on the report, membership totals are:

September 30, 1953		April 10, 1954
7795	Total Membership	8211
32	Members Emeritus	33*
70	Fellows	68
1870	Members	1959
5579	Associate Members	5873
244	Student Members	278

*Includes 12 Fellows.

John H. Waterbury M.E.

On recommendation of the Board of Examiners, Council unanimously elected John H. Waterbury, recently retired after more than 35 years' service to the lighting industry and to the Society, a Member Emeritus of I.E.S.

Light's Jubilee

Activities of the Society's Task Committee on the celebration of Light's Diamond Jubilee were outlined by S. G. Hibben, Chairman. Mr. Hibben's report indicated nationwide participation in this program, with numerous aids to local activity available from the Jubilee Committee, 420 Lexington Ave., New York.

Regional Activities

Recent activities of the ten regions of I.E.S. were reported to Council through a summary submitted by R. F. Hartenstein, chairman, and read by Marshall Waterman, General Secretary. President Manwaring also called on Regional Vice-Presidents present to report in person on their Regions. Glenn Park, Southern Regional Vice-President indicated a Chapter is forming in Little Rock, with two other groups also active in his Region. With this growth in Chapters, he mentioned the problem of the V-P visiting each group and giving individual service. His suggestion of an assistant V-P was referred to the Regional Activities Committee for study.

Other matters reported by the V-P's included the problem of certificates for courses; Regional conferences for next two years; education of local officers in Society procedure, etc.

New Chapter

C. J. Berry, East Central Regional V-P submitted (through A. D. Hinckley) a petition for a charter, from an active group of members in Richmond, Va. Their petition indicated full qualification for an I.E.S. Chapter and Council approved a Charter to the new Chapter to be known as the Virginia Chapter. This reactivates a Chapter established in Richmond a number of years ago.

Sustaining Members

A report submitted by C. C. Shotwell, Chairman, was approved, for the election of the following Sustaining Members:

Canning, Pekara, Inc.
2144 N. Wood Street
Chicago 14, Illinois
Official Representative: Mr. Claude E. Canning

Morlite Equipment Company
P. O. Box 106
Girard, Pa.
Official Representative: Mr. Finley J. Gordon

This committee's proposal for Research Fund solicitation was also further discussed.

Medal Award

On recommendation of the Medal Award Committee, Council unanimously approved Dr. E. F. Lowry as recipient of the I.E.S. Gold Medal. A more detailed account of Dr. Lowry's award to this highest I.E.S. honor is elsewhere in Telecast.

Technical Program

C. L. Crouch gave Council an interesting summary of activities underway by the Society's technical committees. Council took action on the report "I.E.S. General Guide on Photometry" just completed by the Committee on Testing Procedures for Illumination Characteristics. This report was approved for publication.

A number of matters not on the agenda were raised by local members attending Council. Among these were discussions on ways and means of financing contest winners to the National Technical Conference (referred for recommendation to the Regional Activities Committee); breakdown and simple demonstration of Society's financing for member information(referred to Finance Committee'; location of Society headquarters; I.E.S. representation at British I.E.S. meeting this summer.

I.E.S. National Technical Conferences

September 13-17, 1954 — Chalfonte-Haddon Hall, Atlantic City

September 12-16, 1955 — Statler Hotel, Cleveland

September 16-21, 1956 — Statler Hotel, Boston

Opening session of the Southern Regional Conference: left to right, S. L. Drumm, Vice-President, New Orleans Public Service; S. Conrad Berdon, General Conference Chairman; A. H. Manwaring, I.E.S. President; Harry T. Bailey, Jr., Chairman, New Orleans Section; and James E. Fitzmaurice, Councilman representing the mayor of New Orleans.

Southern Regional Conference Leads Off in New Orleans

The first of the nine I.E.S. Regional conferences scheduled this Spring from coast to coast and in Canada, was held April 8 and 9 at the Hotel Roosevelt, New Orleans. In all respects it set quite a pace. Next year's planners, in any Region, could well look into the Southern Region's methods.

Some of the results included member representation from every Section and Chapter in the Region. A marked interest in what went on, by the local press. An attendance of 192, smoothly handled. Valuable education for all delegates. A very good time by all concerned—including, quite likely, the hard-working committee members.

The roster of 192 registered delegates was swelled by 15 out-of-the-region members in town for the Council meeting which followed the conference, April 10. This feature was a repeat of the successful experiment in Dallas last year, when Council traveled to a distant southern city for the first time. Eighteen southern members attended the Council meeting, some as proxies for regular members.

Travel Award

An attendance prize is awarded each year in the Southern Region, to the Section or Chapter attending the Regional Conference in the greatest numbers, in per cent of their total membership and the distance traveled. Georgia Section won this plaque for the third straight time, with 23 members on hand. In addition, although they did not count in the travel award, about 15 Georgia Section wives also attended the conference.

Program Highlights

The stature of the technical program bespoke advance planning. Six sessions were scheduled during the two days of the conference, including major addresses during luncheon meetings. A national-conference touch at these meetings was felt in the full-scale Lighting Progress demonstration by T. C. Sargent at the noon session April 8, and the demonstrated lecture April 9 by S. G. Hibben on "Light's Diamond Jubilee."

A talk of very particular significance was part of the closing session on Thursday afternoon. This was the report by Glenn E. Park, Vice-President of the Southern Region, on "A Look at the Southern Region's Part in the Illuminating Enginering Society." This Region has, of course, taken a very active part in developing and disseminating the Society's objectives in the south, and through them in a healthy advancement of the lighting industry in that area. Mr. Park's discussion of the subject, with the Region's own members, was a very fitting part of the regional program.

Other major addresses of particular value to I.E.S. members were a feature of the opening session. These were made by S. L. Drumm, Vice-President of the New Orleans Public Service Company, James Fitzmaurice, Councilman representing the Mayor of New Orleans, and A. H. Manwaring, I.E.S. President.

The advance planning already noted will be evident from a glance at the technical program listed at the end of this report. Top speakers in their sub-

George Wilkinson, Chairman of the Carolinas Section; Gordon Wells, a delegate from that Section; and J. F. Whitehead, I.E.S. Director.

President and Mrs. Manwaring receive a gift from the New Orleans Section, presented by Section Chairman H. T. Bailey.

At the party given for Council by past V-P of the Southern Region R. C. Pasley are Mrs. Manwaring, Mrs. S. G. Hibben and President A. H. Manwaring.

Judges of the MMILJ Contest in consultation: left to right, C. M. Cutler, George Taylor, Marshall Waterman, M. J. Myers, and Ruby Redford.

ject. Mary Webber, for instance, gave a quite pertinent thought for lighting application engineers to ponder in her talk "Can Today's Home Design and Lighting Prateice Be Harmonious?" She stressed the need for a new approach in their lighting discussions with architects and interior designers. Among other things, this would include presentation of lighting principles in such a manner compatible with the architect-designer's own principles of good design. She proved her point with some beautiful color slides in which interior design and good lighting practice were very harmonious indeed.

C. M. Cutler's talk, also with excellent visual-aid slides, presented step by step some eight methods of lighting shopping centers, with numerous ideas for attracting shoppers.

The current interest in ballast and circuit control devices packed the hall for M. E. Robertson's paper on this subject. The type of inspirational lecture which makes Regional Conferences most valuable to field men was also on the program — twice in fact, by Henry L. Logan and C. L. Crouch. Both practical lighting information and basic visual fundamentals were included in the lectures by James A. Meacham, on "Color" and by Robert D. Burnham on "Classroom Lighting Practice and Economics." Each paper of outstanding value to lighting practitioners.

M.M.I.L.J. Contest

It would be hard to say what feature of a Regional Conference attracts the keenest interest. The contest for "My Most Interesting Lighting Job" is fast running second to none. Six entries were featured in the Southern contest. Results of the contest, in the opinion of a panel of five judges, were as follows:

First Prize — Louis N. Goodman, representing New Orleans Section. Lighting the Lobby and Waiting Concourse of New Orleans Union Passenger Terminal.

Second Prize — Gordon Wells, Carolinas Section. Relighting the First Baptist Church, Asheville, N. C.

Third Prize — Saylors J. Andre, Georgia Section. Lighting for Television Viewing Rooms.

Honorable Mention — Fred G. Astor, Southeast Florida Chapter; Relighting of a Drug Store. Harry L. Rhodes,

In photo at left are the contestants in the My Most Interesting Lighting Job Contest: l. to r., A. D. Wallace, who presented H. L. Rhodes' Florida Chapter entry; L. N. Goodman, New Orleans Section and first prize winner; J. W. Fowler, Tennessee Valley Section; S. J. Andre, Georgia Section and third prize winner; F. E. Lott, who presented F. G. Astor's Florida Chapter entry; Gordon Wells, Carolinas Section and second prize winner. In photo at right, Glenn E. Park, Regional Vice-President, presents the award for first place to Louis N. Goodman.

Harold L. Salaun of the New Orleans Section and Harry Bailey, Chairman of that Section, who acted as proxies at the Council meeting which followed the Southern Regional Conference.

Florida Chapter; Lighting of the New St. Petersburg Federal Savings and Loan Building. S. B. LeCornu and Joe Fowler, Tennessee Valley Section; Relighting a Printing Plant.

Mr. Goodman's installation for the Union Passenger Terminal is, of course, now eligible to represent the Southern Region at the finals of this contest in Atlantic City next September.

Judges for the contest, all members from outside the Region, were: George J. Taylor (Northeastern Regional V-P); Marshall Waterman (I.E.S. General Secretary); C. M. Cutler (Fellow of I.E.S., Great Lakes Region); M. J. Myers (Southwestern Regional V-P) and Ruby Redford (Editor of IE).

SOCIAL PROGRAM

It's not hard to be light-hearted in a city so colorful as New Orleans. The entertainment committee did much to abet this, just the same. New Orleans Section was host, for instance, to all registrants at a cocktail party given Thursday evening at the Court of Two Sisters in the Vieux Carre. The President's reception and buffet supper-dance also moved the conference to the old French Quarter Friday evening, to the restaurant La Louisiane. The unmistakable New Orleans touch was at its best at this affair in the delectable food and the Dixieland music. Part of the fun was seeing the delight of the Manwarings when the host Section presented them with three paintings of typical New Orleans scenes. Three m.c.'s helped make this party très gai — Glenn Parks, the Region's V-P; S. Conrad Berdon, Conference Chairman; and Harry T. Bailey, Jr., Chairman of the New Orleans Section. So did some excellent planning aforehand.

A special program for the entertainment of ladies attending was under the direction of Mrs. Mabel H. Hebert and Mrs. Edna P. Fortier. In addition to the cocktail party and the buffet-dance, a style show and cocktail party was arranged on Thursday afternoon, and a walking tour of the French Quarter Friday morning. This included quaint patios, antique shops and other points of interest in this unique city.

PROGRAM

For the record, details of the program presented are given as follows:

Thursday, April 8, 1954

MORNING SESSION — University Room

Chairman — Harry T. Bailey, Chairman New Orleans Section

Opening Remarks — S. Conrad Berdon, General Chairman, Southern Regional Conference.

Address of Welcome — (Introduction by S. L. Drumm, Vice-President, New Orleans Public Service Inc.) James Fitzmaurice, Councilman, representing the Mayor of New Orleans.

Address: A. Homer Manwaring, President, Illuminating Engineering Society.

"Can Today's Home Design and Lighting Practice Be Harmonious?" — Miss Mary E. Webber, Residence Lighting Specialist, General Electric Co., Lamp Dept., Nela Park.

"Lighting for the Varied Requirements of Shopping Centers" — C. M. Cutler, Illuminating Engineer, General Electric Co., Lamp Dept., Nela Park.

LUNCHEON SESSION — Gold Room

Presiding — John E. Sweatte, Chairman Georgia Section

Lighting Progress Report — T. C. Sargent, Lighting Division Commercial Engineering Dept., Sylvania Electric Products, Inc.

AFTERNOON SESSION — University Room

Chairman — Glenn E. Park, Vice-President Southern Region, I.E.S.

(*Continued on page* 12A)

LIGHTING CALENDAR

Society Events

June 10, 1954—Meeting of the I.E.S. Council, New York, N. Y.

June 17-19, 1954—Midwestern Regional Conference, Jefferson Hotel, St. Louis, Mo.

September 13-17, 1954—Illuminating Engineering Society, National Technical Conference, Chalfonte-Haddon Hall, Atlantic City, N. J.

Industry Events

May 17-20, 1954 — Basic Materials Exposition, International Amphitheatre, Chicago, Ill.

May 19-21, 1954 — Pacific Coast Electrical Association, Inc., Hotel Del Coronado, Coronado, Calif.

June 1-3, 1954 — Edison Electric Institute, 22nd Annual Convention, Atlantic City, N. J.

June 6-11, 1954 — National Association of Electrical Distributors, 46th Annual Convention, Atlantic City, N. J.

June 7, 1954, Week of — Society of the Plastics Industry, Sixth National Exposition, Cleveland, Ohio.

June 20-24, 1954 — The American Society of Mechanical Engineers, Semi-Annual Meeting, William Penn Hotel, Pittsburgh, Pa.

June 21-25, 1954 — American Institute of Electrical Engineers, Summer General Meeting, Los Angeles, Calif.

July 13-15, 1954 — Western Plant Maintenance Show, Pan Pacific Auditorium, Los Angeles, Calif.

September 1-6, 1954 — International Electrotechnical Commission, Golden Jubilee Meetings, University of Pennsylvania, Philadelphia, Pa.

September 8-10, 1954—The American Society of Mechanical Engineers, Fall Meeting, Schroeder Hotel, Milwaukee, Wis.

September 22-24, 1954—Canadian Electrical Manufacturers Association, General Brock Hotel, Niagara Falls, Ont., Canada.

September 27-30, 1954 — Institute of Traffic Engineers, Annual Meeting, Hotel Muehlbach, Kansas City, Mo.

September 29 - October 2, 1954 — International Association of Electrical Leagues, Bellevue Stratford Hotel, Philadelphia, Pa.

October 4-7, 1954 — National Association of Electrical Distributors, Pacific Zone Convention, Mark Hopkins Hotel, San Francisco, Calif.

October 11-15, 1954—American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 17-22, 1954—Society of Motion Picture and Television Engineers, Semi-annual Convention, Los Angeles Ambassador, Los Angeles, Calif.

October 18-22, 1954—42nd National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

October 24-27, 1954 — Board of Governors, National Association of Electrical Distributors, Hershey Hotel, Hershey, Pa.

October 27-30, 1954 — National Electrical
New Orleans, La.
Contractors, Annual Convention, Jung Hotel,

November 8-11, 1954 — National Electrical Manufacturers Association, Haddon Hall Hotel, Atlantic City, N. J.

November 15-17, 1954 — 41st National Foreign Trade Convention, Waldorf-Astoria Hotel, New York, N. Y.

November 15-17, 1954 — American Standards Association, 5th National Conference on Standards and 36th Annual Meeting, Hotel Roosevelt, New York, N. Y.

November 28 - December 3, 1954 — The American Society of Mechanical Engineers, Annual Meeting, Statler Hotel, New York, N. Y.

Supt. Frank D. Lawler, whose School Building Committee insisted on the most comfortable lighting, reports . . . . . .

. . "We wanted the best lighting available so we installed Westinghouse CD Luminaires"

"When we built the new Mary P. Hinsdale School, our School Building Committee insisted on the best and most comfortable lighting available. Westinghouse CD's have certainly lived up to those expectations," reports Superintendent Frank D. Lawler, Town of Winchester, Winsted, Conn.

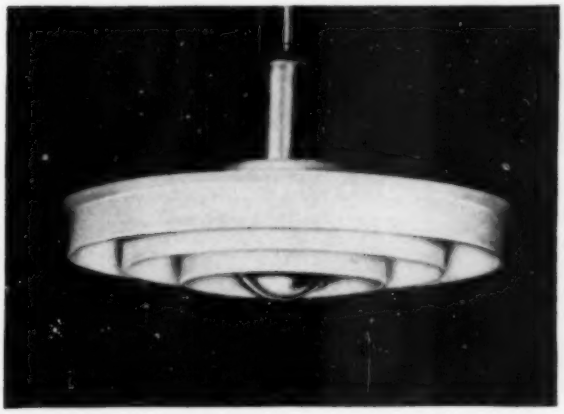
The Westinghouse CD luminaire, with plastic shielding, provides a semi-indirect lighting system. Installed in continuous rows, as is shown in this classroom, the result is an almost glareless system of comfortable lighting. The entire ceiling becomes a part of the lighting system; all lamps are completely shielded.

What's more, the Westinghouse CD makes an attractive addition to the classroom. Its design simplicity fits as a natural part of the background in modern interiors.

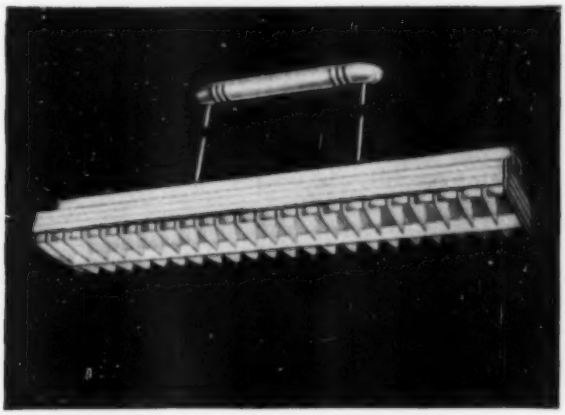
The superintendent further reports, "Our teachers and the school board are very pleased with the new lighting system. Their enthusiasm and that of our parents will undoubtedly influence both future construction and any remodeling of present classrooms."

For other installation methods, get B-4556, "The ABC Plan for School Lighting". Meantime—*look for this seal on your electrical contractor's guarantee. He installs them—we back him up.* Westinghouse Electric Corp., Box 868, Pittsburgh 30, Pa. J-04340-A

And to meet other requirements . . .



Low FIRST cost Concentric Ring incandescent luminaires meet quality lighting requirements on limited funds. Metal rings shield silvered bowl lamps, eliminating glare and shadows.



CC Luminaires mean economy in fluorescent lighting. Low in initial cost—low in maintained cost. CC with X° louver design meets A.S.A. school standards.

YOU CAN BE SURE... IF IT'S
Westinghouse

(Continued from page 9A)

"My Most Interesting Lighting Job" Contest (By winners of contests in Chapters and Sections of Southern Region).

"A Look at the Southern Region's Part in the Illuminating Engineering Society — Yesterday, Today and Tomorrow" — a report by Glenn E. Park, Vice-President, Southern Region.

Friday, April 9, 1954

MORNING SESSION — University Room

Chairman — A. D. Wallace, Chairman Florida Chapter, I.E.S.

"Ballast, Lamp Applications and Circuit Control Devices" — M. E. Robertson, Commercial Engineer, Jefferson Electric Co.

"Practical Solutions to Unusual Lighting Problems" — H. L. Logan, Vice-President in Charge of Research, Holophane Co., Inc.

"Color" — James A. Meacham, Architectural and Maintenance Engineer, The Sherwin-Williams Co.

"A Bushel of Light"—C. L. Crouch, Technical Director, I.E.S.

LUNCHEON SESSION — Grand Ball Room

Chairman — R. L. O'Donovan, Chairman Southeast Florida Chapter, I.E.S.

"Light's Diamond Jubilee" — S. G. Hibben, Director of Applied Lighting, Westinghouse Electric Corp.

AFTERNOON SESSION — University Room

Chairman — Fred M. Niell, Chairman Mid-South Chapter, I.E.S.

"Classroom Lighting Practice & Economics"—R. D. Burnham, Research Engineer, The F. W. Wakefield Brass Co.

"Closing Remarks" — S. Conrad Berdon, General Chairman, Southern Regional Conference.

COMMITTEE WORKERS

All this didn't just happen, of course. A great many hard-working people, from all of the Sections and Chapters within the Region, planned and worked well in advance for the success of this conference. Directing the work were:

S. Conrad Berdon—General Conference Chairman
Glenn E. Park—Regional Vice-President
Harry T. Bailey, Jr., Chairman, New Orleans Section, with R. C. Paslay, and Arthur A. Levy
Secretary-Treasurer—J. M. Gensburger
Papers and Program—Walter T. Faber, with Mario G. Zervigon
Attendance and Publicity—George J. Segel
Hotel, Registration and Reception—Harold L. Salaun, with S. H. Nothacker and Ben Z. Segall
Transportation—Fulton M. Godat, Jr.
Entertainment—Charles C. Kleinschmidt
Ladies' Entertainment—Mrs. Mabel H. Hebert, with Mrs. Edna P. Fortier

Outdoor Lighting Studied By I.E.S. Group in Maine

Three speakers discussed the latest techniques in outdoor lighting at a meeting in Portland, Me., April 1, co-sponsored by the I.E.S., P. E. Weatherbee, Local Representative, and the Electrical Associates of Maine. Gordon V. Miller, Crouse-Hinds Co.; Edward O. Kassman, Westinghouse Electric Corp.; and H. Neel McIntyre, General Electric Co., comprised a panel which discussed outdoor lighting from a safety and protective angle, for advertising purposes and flood-lighting from a civic standpoint.

Home Lighting Workshop Again Offered by San Francisco College

San Francisco State College has announced that its Home Economics Department will for the second time offer a Home Lighting Workshop as an intersession course, during the week of June 28 through July 2. The successful Workshop put on by the college last year was described as the first course on this subject ever approved for upper division college credit. The event last year was offered in cooperation with the Northern California Section of I.E.S. and the Northern California Electrical Bureau.

This year's Workshop will again offer one unit of upper division college credit, and will be, in addition, co-sponsored by the Better Light - Better Sight Bureau.

Three of the nation's authorities on residential lighting will serve on the faculty of the Workshop. They are Miss Mary Webber, General Electric Co., Cleveland, Ohio; Miss Edith Buchholtz, Westinghouse Electric Corp., Bloomfield, N. J. and Miss Jan Reynolds, Sylvania Electric Products, Inc., New York City.

Program of the five-day Workshop is:

MONDAY, JUNE 28

Why Study about Light and Sight — Dr. Gertrude Luehning, San Francisco State College.
Objectives of Today's Lighting Practice — Mary Webber.
Analysis of the Major Visual Activities — Mary Webber.
Requirements for Home Visual Activities — Mary Webber.

TUESDAY, JUNE 29

Light Bulbs and Tubes for Home Uses — Edith Buchholtz.
Light and Color in the Home — Jan Reynolds.
Use of Portable Lighting Equipment — Mary Webber.

WEDNESDAY, JUNE 30

Solution of Specific Visual Problems — Mary Webber and Jan Reynolds.
Surface-mounted Fixtures for Both Local and General Lighting — Edith Buchholtz.
Modernizing Existing Home Lighting — Edith Buchholtz.

THURSDAY, JULY 1

Lighting Solutions for Kitchen, Laundry — Jan Reynolds.
Architectural or Built-in Fixtures — Edith Buchholtz.
Special Architectural Lighting Effects — Jan Reynolds.
Example Cases of Planned Interiors — Mary Webber.
"Bright Future" — Color motion picture produced by the General Electric Co.

FRIDAY, JULY 2

Exterior Lighting — Edith Buchholtz.
"Better than Kings" — Color motion picture produced by Westinghouse Electric Corp.
Discussion of Materials Available for Teaching about Light and Sight — Edward A. Campbell, Manager, Better Light - Better Sight Bureau.
Summary and Closing — Dr. Gertrude Luehning.

An unusual feature of the course, for homemaking teachers and home economists, is the fact that it will be presented directly preceding the national convention of the American Home Economics Association, also in San Francisco (July 6-9). Teachers planning to travel to the city for the A.H.E.A. convention can, therefore, attend the Workshop and obtain a credit toward their master's degree by extending their stay for the extra week.

The lectures, demonstrations and discussions comprising this year's Workshop will be presented in the auditorium of the Pacific Gas and Electric Co. in San Francisco.

Airport Lighting Subject Of Three-Day Conference

A national conference on airport lighting was held April 27-29 at the Astor Hotel in Milwaukee. The conference was sponsored by the I.E.S. Committee on Aviation Lighting; the Aircraft Committee, Lighting and Marking Panel; and the N.E.M.A. General Engineering Committee, Aviation Ground Lighting. The Airline Pilots Association and the Air Transport Association participated in the sessions.

Presiding at the meetings were D. C. Miller, I.E.S. Aviation Lighting Committee Chairman; G. M. Kevern, Lighting and Marking Panel Committee Chairman; and W. F. Davies, N.E.M.A. Committee Chairman. R. E. Madigan of Line Material Co. and L. C. Lattin of Hevi-Duty Electric Co. handled the meeting arrangements for their companies, who were hosts for the conference.

M.M.I.L.J. Contest Goes 3-D in Chicago

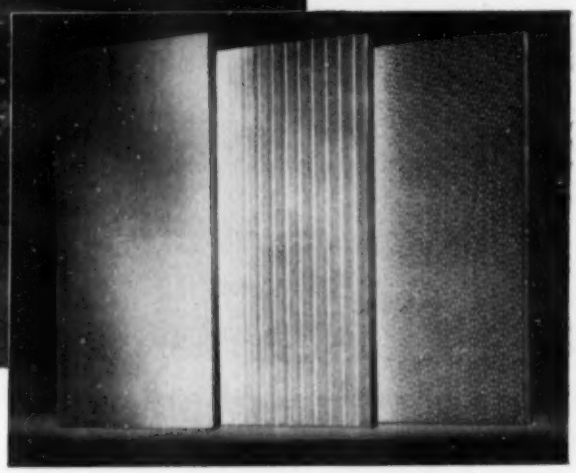
The Chicago Section of I.E.S. featured a new angle to their contest for My Most Interesting Lighting Job this year. Three-dimensional photographs were taken of the 17 installations entered in the competition, to give that extra something to the presentation. The audience, of course, was provided with 3-D glasses. The photographs were taken by Arthur Rosenstein, Chicago Section member.

Another new idea which the Section featured was an "outjudge the judges" contest for the audience, who marked tally cards with their own scoring of the entries. The member with the final tally card closest to the judges' decision won a ten-dollar prize. The winner of this audi-

(Continued on page 15A)

Carey's Luggage Store, Elmira, N. Y. Alba-Lite panels assure evenly diffused, shadow-free and glare-free illumination throughout. PYREX brand Lenslites focus light on merchandise to enhance buyer interest.

Alba-Lite is available in 3 flat patterns (as shown) in sizes up to 24" x 100", in standard bent shapes or bent to order. Ask for Bulletin LS-43.



How lighting helps lure travelers to this luggage store

Every retailer has the problem of attracting more customers in order to sell more merchandise.

Here's an example of how Corning engineered lighting helped solve that problem for Carey's Luggage Store, Elmira, N. Y.

Carey's needed lighting that would be decorative as well as efficient. That's why Alba-Lite was selected. And you can see how well Alba-Lite fills the assignment.

Smithcraft Area Illumination, utilizing large panels of Alba-Lite, provides 100 f.c. of evenly diffused, glare-free and shadow-free light. Merchandise is presented to customers in its rich, sales appealing best. That's because Alba-Lite transmits the true color of the light source. Fixture efficiency is high—yet panel brightness is low.

And the lighting and decorative advantages Carey's is enjoying today will never diminish. Alba-Lite won't fade or discolor or warp with age or atmosphere. Its smooth surface is easy to clean. It keeps its new look.

Use Lenslites for Emphasis

PYREX brand Lenslites with 150-watt lamps and mounted in Litecraft fixtures focus attention on gift and decorative items. The illumination level on counters beneath the downlights is 200 f.c. and on the display shelves it is 100 f.c. Two center Rambush ceiling downlights draw buyers to items in the showcase below . . . boost profitable impulse sales.

You can achieve equally effective results with Corning engineered lighting for schools, hospitals, offices . . . in just about every lighting project that comes your way. For additional information, write for the new Architects and Engineers Handbook. It's filled with helpful and useful information. Send the coupon today.

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Please send me a copy of the new Architects and Engineers Handbook LS-43.

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Address.....

City..... Zone..... State.....

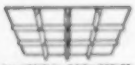
Here's the Modern Way to Light a Factory ... Using Wakefield Industrial Pacemakers

The Industrial Pacemaker is a rugged steel luminaire with all major reflecting surfaces porcelain enameled. Note that the removable side panels unhook and hinge downward for easy, safe maintenance. ETL approved, brick type ballasts deliver full rated lamp watts. For pre-heat, Rapid Start or Slimline lamps.

Note the abundance of light. Note how uniformly it is distributed. Note especially the lighted ceiling area. Only a luminaire like the Wakefield Pacemaker will give these results, for the Pacemaker transmits 25% of the light up to the ceiling to be reflected in an over-all distribution pattern all over the room.

Now note again the lighted ceiling area. Not only is this the very key to modern plant lighting, but it has the added advantage of facilitating maintenance in the upper area. Listen to what one midwestern plant superintendent says: "In parts of our plant where we use reflectors which do not allow any light to go upward, the underside of the roof and the structure beneath is black and it is impossible to see piping or other structural parts for inspection or maintenance." Those black overhead caverns in plants are out-moded, inefficient and, thanks to the Pacemaker, unnecessary. For a folder on the Industrial Pacemaker, write to *The F. W. Wakefield Brass Company, Vermilion, Ohio. In Canada, Wakefield Lighting Limited, London, Ontario.*

Wakefield Over-ALL Lighting


WAKEFIELD GEOMETRICS

THE CAVALIER

THE GRENADIER

THE PACEMAKER

THE COMMODORE

THE STAR

THE WAKEFIELD CEILING

(*Continued from page* 12A)

ence participation award was W. T. Gill, of Martin and A. Moffet, electrical contractors.

Winners of the contest itself were:

First prize—Vernon T. Kempf, consulting engineer, for Ryerson Steel Warehouse installation.

Second prize—Sobel & Stein, architects, for the Komiss Store.

Third prize — C. N. Carlson, of Public Service Co., for the Wilmette, Ill., Public Service Store.

Judges for the competition were Professor John O. Kraehenbuehl, University of Illinois; Albert Schlachtmeyer, Perkins & Wills, architects; and Carl Zersen, Director of the Chicago Lighting Institute.

Cleveland Section Sponsors Inspection Tour Series

Members of the Cleveland Section, I.E.S., were given an opportunity to get an inside look at several other different businesses recently, when the Education Committee under the chairmanship of T. J. Wood, arranged a series of inspection tours.

On April 8, the subject was paint, with a tour of the Sherwin-Williams Paint Co., supplemented by a talk on paints. The following week, on April 16, the Akerman Molded Plastic Co. was visited. Graphic arts were looked into April 22, when the group inspected the Art Gravure Corp. of Ohio and the *Cleveland News*, one of Cleveland's fine newspapers. The final tour, April 30, was a "behind-the-scenes' visit to WNBK Television studios.

A nominal service charge of one dollar covered all four trips.

ISCC Annual Meeting Held in New York City

The 23rd Annual Meeting of the Inter-Society Color Council was held March 24 at the Hotel Statler in New York City, with an attendance of 136. The sessions included the annual business meeting and reports by the following problem committees:

Color Names
Survey of Color Specification
Color Aptitude Test
Color Blindness
Studies of Illuminating and Viewing Conditions in the Colorimetry of Reflecting Materials
Study of Transparent Standards Using Single-Number Specifications
Definition of Color Terms
Standard Methods for Mounting Textile Samples for Colorimetric Measurements
Color in the Building Industry
Colorimetry of Fluorescent Materials
Study of Near-White Surfaces

These committees are composed of individual members of the Council and representatives from its nineteen member organizations, including the I.E.S.

The banquet was highlighted by a lecture-demonstration of color television presented by Ray D. Kell, head of the Television Section of RCA Laboratories in Princeton, N. J.

Further information on the Council and its activities may be obtained by writing to the Secretary, Ralph M. Evans, Eastman Kodak Co., Kodak Park Works, Rochester 4, N. Y.

E.E.I. Sponsors Portable Lamp Selling Program

The formation of a new practical portable lamp selling program has been announced by J. Reed Hartman, chairman of Edison Electric Institute Commercial Division, and vice-president of Cincinnati Gas and Electric Co.

The new activity will be called the "Beauty-plus Lamp Program." As the name indicates, the portable lamps offered will provide decorator styling plus adequate, diffused lighting for seeing tasks. Another plus of these lamps is approved electrical construction; Underwriters' Laboratories approval will be indicated on all lamps.

An outline of the plans for the lamp selling promotion was presented to the representatives of electric service companies attending the E.E.I. Sales Conference. First showing of the new lamps will be at the Summer lamp shows.

Lamps included in the program must meet specifications set up by the "Beauty-plus" Lamp Council, the organization created to correlate the program. The lamps must provide good lighting, as outlined by their specifications, meet Underwriters' Laboratories standards electrically and meet the shade and size dimensions set up by the Council.

Specifications call for such lamps to include Certified Lamps, reflector-bowl types and R-40 type white indirect lamps. It is estimated that these specifications will admit most of the lamps already using these lamp heads, according to one lamp manufacturer.

Lamps meeting the specifications will be tagged. A unique feature of these tags is that it will indicate the proper size bulb to assure customer satisfaction. A lamp wearing the "Beauty-plus" tag indicates that it meets the specifications set up by the E.E.I. Lamp Council.

Engineering Educators To Meet at U. of Illinois

Over 1500 engineering educators are expected at the annual meeting of the American Society for Engineering Education on June 14-18 at the University of Illinois, Urbana, Ill. The meetings will include conferences sponsored by the Engineering College Administrative Council and the Engineering College Research Council, which are two component organizations of the A.S.E.E.

The theme of the conference this year, "Evaluation of Engineering Education," will feature a thorough analysis of all phases of engineering education, conclud-

(*Continued on page* 16A)

SOME of the 136 persons attending the 23rd Annual Meeting of the Inter-Society Color Council.

(Continued from page 15A)

ing a two-year study on the subject undertaken by the A.S.E.E.

A Golden Anniversary dinner will be held June 15, in honor of the 50 years' operation of the engineering experiment stations of the University of Illinois and Iowa State College. Speaker at the dinner will be Dr. Lee DuBridge, President of the California Institute of Technology.

Annual Spring Program Presented by C.L.I.

The Lighting Fundamentals Course, with lectures by Raymond Wozniak and laboratory sessions with James Burke, is being presented again this year by the Chicago Lighting Institute. The 1½-hour lecture series take place weekly from April 5 to June 21. The 2-hour laboratory classes are being held every other Thursday from April 8 to June 17.

Also an annual event is the course in Wiring Design Number 1 with Frank R. McShane as Instructor, with classes every Tuesday from April 6 to June 22. Wiring Design Course 2A will be offered during the fall quarter.

Sessions for both courses are held at the Institute and tuition is $25.

Two I.E.S. Chapters Hold Birthday Party Meetings

Glenn E. Park, Vice-President of the Southern Region, I.E.S., and A. D. Hinckley, the Society's Executive Secretary, were the guest speakers at two meetings held in the Southern Region.

The Alabama Chapter was celebrating its first birthday on April 5, having received its Charter on the same day in 1953. The anniversary meeting was held at the Thomas Jefferson Hotel in Birmingham, Ala. Mr. Park spoke on the friendly relations and cooperation needed within the Chapter to realize the ambitions of both the Chapter Chairmen and their Regional Vice-President in their achievements for themselves and for the Society. He also stressed the value of the contests for "My Most Interesting Lighting Job," urging all I.E.S. members to do at least one oustanding installation in the next year.

Mr. Hinckley spoke on the national organization of the Society and how it works, using examples from the Council agenda to illustrate the Society's program, the kind of decisions which must be arrived at by Council (through membership representation by its elected officers). In each case the relations of the headquarters office and its functions were given.

At the April 6 meeting of the Mississippi Chapter, at the Walthall Hotel in Jackson, Miss., Mr. Park and Mr. Hinckley were again guest speakers. By a coincidence, this meeting was likewise an anniversary, since the Mississippi Chapter dates from April 6, exactly four years ago.

Advanced Lighting Conferences Continue Pittsburgh Program

A series of advanced lighting conferences have been sponsored by the Pittsburgh Section of I.E.S. in cooperation with the Electric League of Western Pennsylvania. The program was under the direction of the Section's Education Committee, H. S. Orton, Chairman; and was held at the Westinghouse Electric Conference Room, Union Bank Building in Pittsburgh. Topics and speakers at the two hour conferences were:

April 12 — Trends in Industrial Lighting — Lucian T. Kight, Duquesne Light Co.
Industrial Lighting Panel Discussion, H. S. Orton, Moderator, West Penn Power Co., and panelists A. A. Paulus, Westinghouse Electric Co., C. R. Crysler, General Electric Co., and Don Thomas, Sylvania Electric Products Inc.

April 19 — Calculation and Design of Luminous Ceilings — George Clark, Sylvania Electric Products, Inc.
Acoustical Design and Calculation as Applied to Luminous Ceilings — a representative from Owens-Corning Co.

April 26 — Architectural Flood Lighting — a representative from Illuminating Laboratory, General Electric Co.

Architectural-Construction Center To Be Erected in Miami

Plans for a comprehensive architectural, engineering and construction industries center, to be erected in Miami next year, have been announced by Clinton T. Wetzel, President of the Architect's Samples Bureau now located at 5040 Biscayne Boulevard, Miami. It will be known as Du Pont Plaza Architectural and Construction Industries Center.

The project, inspired by the success of the present Bureau, will form a nerve center serving the arts and sciences of the building and construction industries in Greater Miami and South Florida. Located in the heart of the downtown business district, the center will have 75,000 square feet of floor area devoted to permanent graphic displays of products of the building materials industries. An architectural library is planned, with adjacent club and conference rooms in conjunction with the South Florida Chapter of A.I.A., whose headquarters will be

(Continued on page 18A)

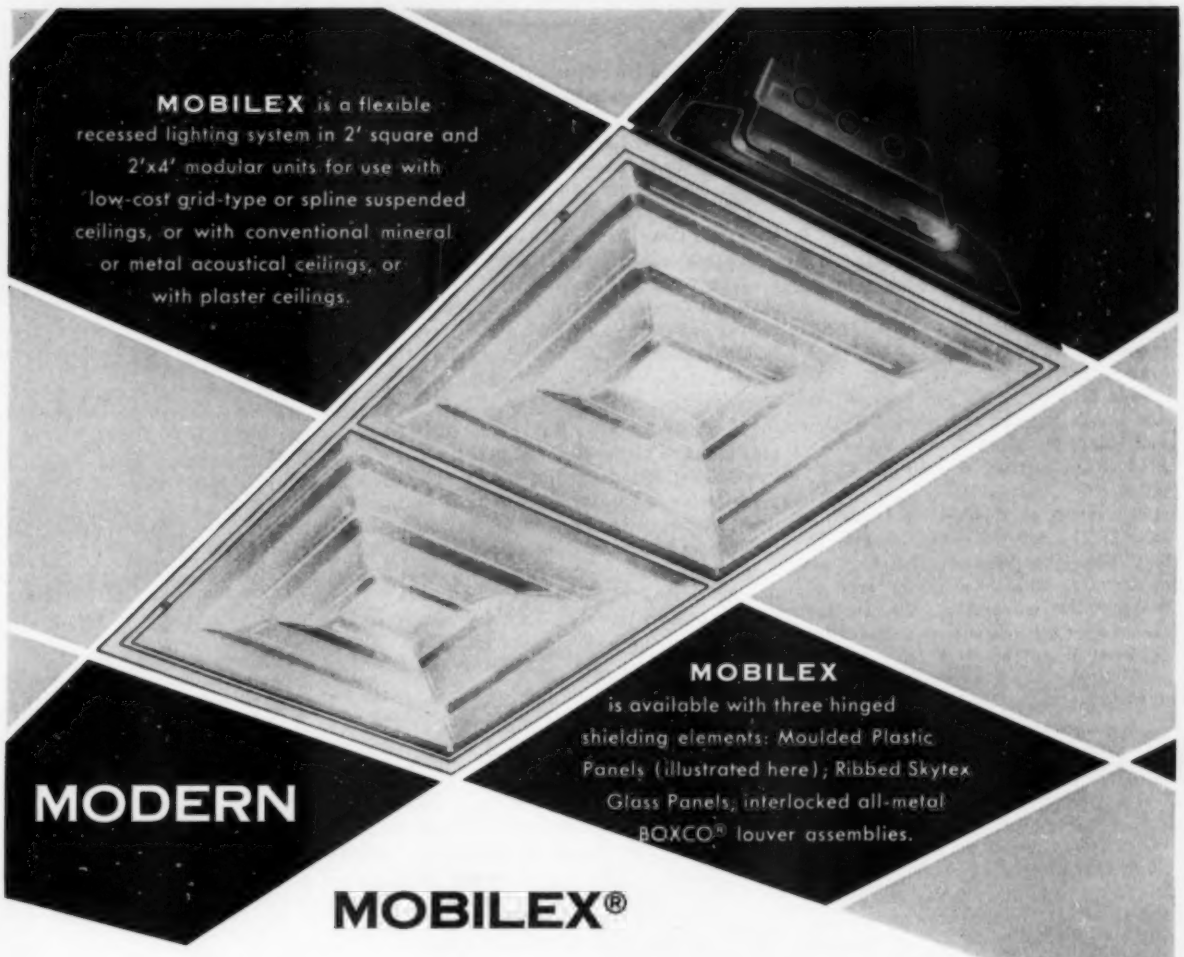
Where To Get Light's Diamond Jubilee Materials

Materials for participating in Light's Diamond Jubilee may be obtained from:

Light's Diamond Jubilee Committee
2650 Graybar Bldg.
420 Lexington Ave.
New York 17, N. Y.

Item	Prices
Plan Book	*You will receive one copy free.* Additional copies are $1.25 each.
Fact Book	$1.00 each for 1-24 copies .75 each for 25-99 copies .50 each for 100 or more copies
Jubilee Medallions (3-inch bronze)	$3.50 each for 1-24 medallions 2.75 each for 25 or more medallions
Letterhead Stickers (Type A, 2" x 1")	Emblem face and reverse together; gummed back. $2.75 per thousand stickers.
Letterhead Stickers (Type B, 1" diam.)	Combined emblem, gummed back. $2.50 per thousand stickers.
Window Stickers (Type A, 6" x 3")	Emblem face and reverse together; gummed face. $6.00 per thousand.
Window Stickers (Type B, 3" diam.)	Combined emblem, gummed face. $3.00 per thousand.
Emblem Photos	$1.00 for four prints or fraction.
Emblem Proofs	*You will receive 6 free reproduction proofs with order.* Additional proofs are $1.00 for 12 or fraction.
Postmark Ad Plate for Pitney-Bowes Model	$15.00 each for 1-4 plates. $13.50 each for 5 or more plates, same model. *Be sure to give model number.*

Order blanks available for convenience in ordering.


MOBILEX is a flexible recessed lighting system in 2' square and 2'x4' modular units for use with low-cost grid-type or spline suspended ceilings, or with conventional mineral or metal acoustical ceilings, or with plaster ceilings.
MOBILEX
is available with three hinged shielding elements: Moulded Plastic Panels (illustrated here); Ribbed Skytex Glass Panels; interlocked all-metal BOXCO® louver assemblies.
MODERN

MOBILEX®

You can solve more problems with MOBILEX *... less expensively ... than with any other recessed lighting fixture*

How many times in your experience have you wanted to use the good design advantages of recessed lighting—only to see your plans go by the boards because over-all ceiling costs get out of line?

You have an answer to that bottleneck now. MOBILEX. *It fits more types of ceilings—without the need of expensive custom made adapters—than any other recessed lighting fixture on the market.* That means MOBILEX gives you a broader range of price, ceiling and recessed lighting combinations than you've ever had to work with before.

MOBILEX reduces installation time up to 50% when used with certain types of ceilings. That means important savings when you're working with a limited budget.

Because we know you are always interested in new products that *really help you do a better job*, we think you'll want to see and hear more about MOBILEX. We'll be happy to arrange a MOBILEX demonstration any time you say. We promise you this: you'll find it well worth-while.

WRITE FOR BULLETINS OD-567 AND OD-606

447

DECIDEDLY BETTER
DAY-BRITE
Lighting Fixtures

Day-Brite Lighting, Inc., 5432 Bulwer Ave., St. Louis 7, Missouri. In Canada: Amalgamated Electric Corp., Ltd., Toronto 6, Ontario.

CALL OR WRITE YOUR NEAREST DAY-BRITE REPRESENTATIVE

(Continued from page 16A)

housed in the center. An auditorium, television studios and recreational area are also in the plans. Near-by will be a hotel and office building.

The entire project will cost an initial $5,000,000 and will represent an investment of over $10,000,000 when completed.

Poor Preparation Blamed for Inadequate Engineering Education

The declining amount and quality of preparation for an engineering education offered by the nation's public high schools is perhaps the most important problem facing the engineering profession today, according to an editorial in *Product Engineering*, McGraw-Hill publication.

The extent of this decline is clearly indicated by the "refresher courses" in high school mathematics that are required of freshman students by some of the technical universities. The student cannot start his college level mathematics until his second or third semester, the editorial points out.

A recent report, issued by two engineering societies, emphasized that 28 per cent of the engineering graduates stated that they did not feel that their college training had prepared them adequately for an engineering career. Also included was the often heard criticism that engineering colleges do not teach enough literature, writing and the humanities. Poor preparation at the high-school level, the editorial suggests, is the greatest single cause for the limited scope of engineering college curricula.

Only state legislatures can rectify this situation, and only the pressure of public opinion will bring about the needed changes in the high schools, the editorial points out.

The societies for engineering education, although fully cognizant of the situation and doing practically all that they can, are not capable of handling such a situation, and the high schools themselves are equally unable to get the needed results. The "old line" national engineering societies steer away from public questions of a non-technical nature. Although some some of these groups have tried to include the fostering of engineering education as one of their objectives, they feel that public schools and related problems are linked too closely with politics, the editorial says.

The one exception to this general attitude seems to be the National Society of Professional Engineers; apparently this organization is much more active in matters affecting engineering education, training and careers. It remains to be seen whether the older societies will relinquish to the NSPE the leadership that will bring about better engineering education and training and that will bring to the profession greater recognition and esteem.

Food Store Lighting Campaign Underway in New York City

In a drive to promote improved food store lighting, a Planned Lighting for Food Stores campaign was started in New York City and Westchester County by Consolidated Edison's Sales Department. In the campaign's first month, February, more than 700 requests for lighting studies were received on how to improve store and display lighting. The studies, made by the Lighting Division of the Sales Engineering Bureau, are specially tailored for each individual store owner—including number, type and wattage of lamps recommended, spacing, suspension, control, and the estimated illumination level that will result. Diagrams show different luminaires available and how they can be used to achieve maximum effect for overall store illumination or for highlighting display counters, merchandise shelves and racks.

School Lighting Conference Held at Nela Park

A three-day conference for school executives and architects was sponsored by General Electric's Lamp Division, April 26-28, at the Lighting Institute at Nela Park. Subjects discussed in the three sessions were:

MONDAY, APRIL 26

Seeing in the Schoolroom — A Resume of 30 Years of the Lighting Research Laboratory.
Lighting Terms and Fundamentals.
Demonstration and Discussion of Classroom Lighting Techniques.
Lamps Commonly Used in Schools.

TUESDAY, APRIL 27

Comfortable Lighting — Quality Light Control.
The Importance of Maintenance.
Lighting the Way to Learning.
The Need for Proper Wiring.
Lighting for Study at Home.
School Shop Lighting Requirements.
Facilities for Visual Education.
Library Lighting.

WEDNESDAY, APRIL 28

Lighting for Displays and Exhibits.
Germicidal Lamps and Their Applications.
Auditorium and Stage Lighting.
Lighting for Offices and Drafting Rooms.
Gymnasium, Outdoor Sports and Grounds Lighting.

Plastics Conference to Run Concurrent with Exposition

Leading manufacturers who use plastics in their products will explain how and why at the Technical Conference that will be held concurrently with the 1954 National Plastics Exposition, sponsored by the Society of the Plastics Industry, Inc., June 7-10, 1954 at Cleveland's Public Auditorium.

All phases of plastics manufacture will be represented in exhibits planned — molding; lamination; extrusion; fabrication; reinforced plastics products; film, sheeting and coated fabrics; raw materials; machinery and equipment; and testing and research methods. Exhibitors will display and discuss the most recent technical advances in plastics industry.

The national Plastics Exposition is sponsored by the Society of the Plastics Industry, Inc., New York, a trade and technical society representing the plastics industry throughout the United States, Canada and 20 other countries.

(Continued on page 21A)

FOUR of the members of the New York Section, I.E.S. who were in on the planning of the Section's recent School Lighting Clinic, are: l. to r., Section Chairman E. M. Fahey, H. E. D'Andrade, Harold Peters and Lou Goren.

Formed pan diffusers of PLEXIGLAS provide large-area luminosity and fixture-free appearance in ROOM LIGHTING.

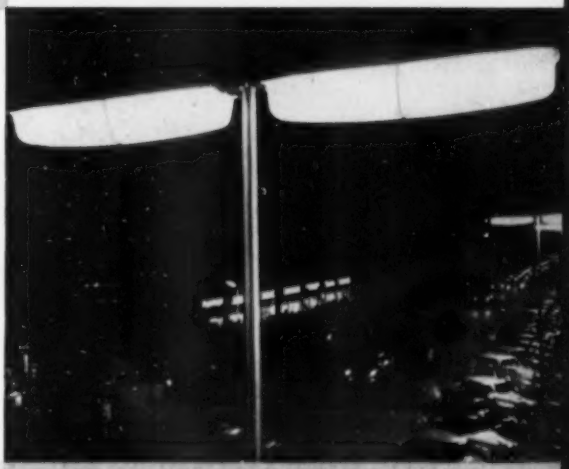
PLEXIGLAS

the outdoor plastic— for Trouble-Free Lighting

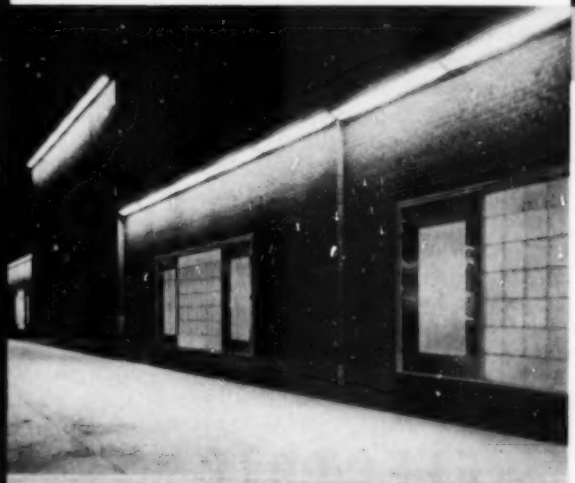
A plastic that can be used *outdoors* is your best assurance of trouble-free service in interior installations.

PLEXIGLAS acrylic plastic is noted for its dimensional stability, freedom from discoloration and resistance to breakage, regardless of the point of use. That is why it is the preferred material for diffusers, covers, and shields on lighting fixtures.

For outstanding durability, and maximum efficiency in the transmission and diffusion of light, specify PLEXIGLAS. We will be glad to supply details on the usefulness of this multi-purpose lighting material.



Injection-molded PLEXIGLAS covers protect fluorescent lamps in this new type of STREET LIGHTING.



PLEXIGLAS shields protect the light source in this unique SIDEWALK LIGHTING installation.

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YOU EXPECT THE BEST VALUE FROM G-E FLUORESCENT LAMPS

Invisible coating helps new G-E Rapid Start Lamps light faster

THE film of water that condenses on a fluorescent lamp in wet weather is so thin the lamp hardly feels damp. Still, it can connect the ends of the lamp and set up a miniature short circuit. It doesn't injure the lamp. Just steals enough current so the lamp is slow in lighting.

There's one fluorescent lamp, though, that doesn't get sluggish in moist air: the General Electric Rapid Start Lamp.

It has an invisible coating of General Electric silicone, called Dri-Film*. The photo shows what it does to water on the lamp. Makes it stand up in separate drops. In between are dry areas that break the electrical contact. The short circuit doesn't get started. The lamp does.

G-E Dri-Film* doesn't rub off. It's an example of why you expect the best value from G-E fluorescent lamps. For free booklet, "Facts About Rapid Start", write to General Electric, Dept. 166-IE-5, Nela Park, Cleveland 12, Ohio.

*REG. U. S. PAT. OFF.

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GENERAL ELECTRIC

Oregon State Student Branch Discusses Classroom Lighting

The Oregon State College Student Branch of I.E.S. feels that its recent meeting on classroom lighting was one of the best of the year. A model classroom was brought to the campus by the Portland General Electric Co., and classroom lighting was discussed and demonstrated by J. T. Cottingham and D. A. Maulding of that company. This was followed by a talk on home study lighting by Mrs. Grace Schoeni, also of Portland General Electric.

The meeting, which was sponsored jointly with the student branch of the American Institute of Electrical Engineers, was considered of interest to others than engineering students; and an invitation was extended to the public, a number of whom attended.

IT SEEMS TO ME

Lighting a TV Antenna Tower

This comment refers to the article by E. J. Whitlow, "Lighting a TV Antenna Tower," which appeared in the December 1953 issue of I.E.

Why not paint the *inside* of all the tower structure members white to provide a good reflecting surface and mount lighting units at proper levels *within* the limits of the tower structure? This method would provide just as much tower surface in the line of vision (less the interference of forward members) and you would have a chance to light the observable structure more efficiently, more certainly, and easier and cheaper. I would like to see someone try out this idea. WM. P. BEAR, *Member Emeritus, I.E.S., 8344 Lullaby Lane, Van Nuys, Calif.*

Prefabricated Coffer Ceilings

Referring to the article, "Prefabricated Coffer Ceilings," it was the fluorescent lamp which made large area lighting an economical proposition. With incandescent lamps, such a scheme always proved to be very costly to run.

With fluorescent lamps available three distinct designs have developed: the luminous ceiling, the louverall ceiling and the indirect coffer type. Every one of these designs is being favored more or less by architects, lighting engineers and others and even a certain trend of what could be called a national taste can be discerned. If for a moment generalization be permitted it seems that for instance the U.S.A. is giving some preference to luminous ceilings and recently to the indirect version — the coffer ceiling. Australia to a large degree rejects the luminous ceiling and prefers the plastic eggcrate louvering. On the other hand the merits of the prefabricated indirect lighting of the coffer type are being recognized in Australia and the idea advanced.

Therefore the article "Prefabricated Coffer Ceilings" by Laurence S. Harrison (published in "I.E." December 1953) is being met with interest in Australia and the two installations shown are well known and appreciated since they were first published previously. But when studying the mentioned article a few points need clarification.

In the introduction the author says that plaster coffers "designed and applied properly have their virtue in high output with low relative brightness." Lighting engineers, queer as they sometimes are, will probably prefer this thought expressed more correctly as "high luminous efficiency with a relatively low brightness" and it is assumed that this low brightness is meant to be relatively low as compared with some kind of direct lighting system.

The author further claims in the next sentence (having praised the coffer ceiling's high efficiency and relatively low brightness) that "this is due to the presentation of a greatly increased area of reflecting surface from inside the coffer through its opening — resulting in more effective horizontal distribution than the distribution with light transmitted through either flat glass or plastic sheets."

This is a rather sweeping statement. The efficiency of a well designed coffer ceiling may be high compared with a badly designed indirect lighting system but every other kind of lighting will be more efficient. Efficiency of course is not everything and architectural effect as the two illustrations of the Harrison installations show may be much more important.

But as the author made certain statements about efficiency let us look at the efficiency (called "output") a bit closer.

The efficiency of a single coffer is not simply a function of the size of its reflecting surface but rather of its shape, reflectance and *apparent* size or horizontal projection. A certain percentage of the luminous flux of the lamps reaches the reflecting dome surface and after a diffused reflection a smaller percentage of the luminous flux leaves the open square which forms the base of the dome, its horizontal projection. The difference between incident flux and reflected flux (the loss through reflection) is a function of the reflectance of the dome and of its shape. The correct shape will be the one with a minimum of multiple reflections against an optimum of single reflections. A mathematician only can determine the theoretically correct curvature for such maximum efficiency and then of course the question would arise whether such a dome can easily be mass-produced. But as mentioned before the efficiency is not all important and there is hardly a need for a mathematical investigation into this matter as the good installations described by Mr. Harrison show.

It is not clear why a coffer should give a more effective horizontal distribution than a luminous ceiling whatever "effective horizontal distribution" may mean. Perhaps the author could claim for a small area installation higher vertical illumination levels than a luminous ceiling of the same size would give. But even this is doubtful and for the practical lighting engineer there is a simple way to prove it: the test. As far as horizontal light distribution is concerned there should hardly be a difference between luminous ceiling and indirect coffer lighting and Mr. Harrison may be in for some criticism for Domina Eberle Spencer and her group in this respect.

The author claims further that plastic sheets as used for transmitting light (meaning for luminous ceilings) are now being installed in a more efficient way in the form of inverted domes "to approach performance efficiency of coffers in a comparable arrangement." (By the way why inverted domes? The dome of St. Peter's in Rome is surely not inverted. Or is it?)

The plain facts are that better reflecting materials than plaster, for instance aluminum or steel with appropriate finish or plastics are being used for reflecting the light. But surely Mr. Harrison does not suggest that the same plastic sheets used in luminous ceilings for light *transmission* and *diffusion* are now being used as *reflectors* in indirect coffer lighting. Would he not prefer a more opaque type of plastic?

Publications in ILLUMINATING ENGINEERING are as a rule of a very high standard and the journal has acquired over the years a good reputation overseas. Even if statements and opinions in articles and papers do not necessarily represent the policies or opinions of the I.E.S. it is suggested that certain statements in articles to be published should be checked in order to keep up the desirable high standard. Less discriminating readers may get wrong ideas from an article like the one criticized. It is felt that a simple treatment of the matter would have given more justice to an idea which in its practical aspects has its undoubted merits. P. J. GRUNDFEST, *Clave Neon Ltd., Randwick, N.S.W., Australia.*

(Continued on page 22A)

Maintenance Factors for Industrial Fluorescent Luminaires

In Table 9-2 in our *Lighting Handbook*, the maintenance factors for fluorescent industrial luminaires are .65 for good conditions, .55 for medium conditions, and .45 for poor conditions. When an engineer uses say the .55 value in a 50-footcandle plan, and the system is installed, and the lights are turned on, at the hundredth hour, he should read — not 50 footcandles, of course, but 50 divided by .55 or about 90 footcandles. Thus the system initially produces about 40 footcandles more than design footcandles or about 1.8 times design footcandles. For good conditions it would be 1.5 times or 75 footcandles; for poor conditions, it would be 2.2 times or 110 footcandles.

No account seems to be taken of this initial head start in maintenance papers in I.E. It seems to me that we have been painting things a little too black (or dark gray) when we choose initial footcandles, as most authors do, as the base for maintenance appraisal of lighting systems. Shouldn't we rate maintenance (or lack of it) on design footcandles? If we do not, we virtually ignore the engineer's foresight — using a maintenance factor — altogether.

In the ten papers on maintenance published by our Society in the past thirty years, every author — Wylie in 1953, Egeler and VandenBoom in 1951, Jacobus in 1950, Tillemans in 1948, Moon and Spencer in 1946, Gaetjens in 1945, Heitzman and Knapp in 1943, Holmes and Conklin in 1942, Gaetjens in 1942, and Anderson and Ketch in 1924 — used initial footcandles. It seems to me that this isn't fair to the designer. K. A. STALEY, *General Electric Company, Cleveland, Ohio.*

Total Luminaire Efficiency

In order for an engineer or architect to properly choose between the use of different types of lighting equipment he must now consult several sources of data. The luminaire manufacturer generally has available information on the efficiency of his luminaires. From the manufacturer of the lamps there can be obtained data on lamp efficiency and in order to obtain data on the power consumed by the auxiliary it is necessary to consult the manufacturer of this equipment.

For a realistic evaluation of different types of equipment, all of the above information is necessary. The luminaire manufacturer, however, can by giving a single figure, which we shall refer to as the "total luminaire efficiency," supply the most important information available from the previously mentioned data. The total luminaire efficiency is equal to the luminaire output (lamp lumens times luminaire efficiency) divided by the lamp wattage plus the wattage consumed by the auxiliaries.

This figure would be useful in comparing the various types of fluorescent lamps and auxiliaries available. It would serve also to clear up potentially misleading situations. For example, a hi-hat type of luminaire using a reflector lamp may have an efficiency of 100 per cent. A comparable lens type of downlight may have an efficiency of only 60 per cent. It would appear that the hi-hat is 67 per cent more efficient. The hi-hat, however, has a total luminaire efficiency of 10 lumens per watt while that of the lens unit is 10.5 lumens per watt, completely reversing the picture.

It is suggested that luminaire manufacturers list a value for total luminaire efficiency with their published luminaire data. This will give the engineer and architect a handy tool to help him in choosing his lighting equipment. IRVING E. COHEN, *Designer, 237 E. 92nd St., Brooklyn, N. Y.*

ABOUT PEOPLE

John H. Waterbury, who retired last August as Chief Illuminating Engineer with Benjamin Electric Manufacturing Co., was elected to the grade of Member Emeritus of the I.E.S. by action of the Council on April 10. Mr. Waterbury, who joined the Society in 1919, has made many contributions to the I.E.S. and the lighting industry through both his original work and his service on the Society's technical committees.

Carter Lewis, Union Electric Co. of Missouri, St. Louis, has been appointed Vice-President of the Midwestern Region to fill the vacancy left by the resignation of **C. B. Pederson.** Mr. Lewis appointed by action of the I.E.S. Council on April 10, will serve in this office until September 30, 1954.

Dan Dunne is leaving Lighting Products, Inc., Highland Park, Ill., on May 15, to accept the position of President of Penn Union Electric Co., in Erie, Pa., manufacturers of electrical cable connections.

R. W. McKinley has joined the Product Development Dept. of the Pittsburgh Plate Glass Co. as Technical Representative. Mr. McKinley was formerly a Development Engineer with Pittsburgh Corning Corp.

J. Roy Jones, of Westinghouse Lamp Division's commercial engineering department in Bloomfield, N. J., has been promoted to the status of regional engineer, W. B. Gero, department manager, has announced. Mr. Jones, who has been with Westinghouse for seven years, has been assigned to the company's Los Angeles office. He assumed his new post early in April, replacing **E. F. Larson,** who has joined the company's Electronic Tube Division. Mr. Jones, chairman of the I.E.S. Committee on Lighting Design Practice, is co-author with **J. J. Neidhart** of a series of studies on methods of making interior lighting calculations.

T. C. Hugh, of the Frink Corp., will attend the meeting of the British I.E.S. at Southport, England, May 18-21. He is addressing this conference for our Society, describing the activities of the I.E.S.

DeWitt C. Herrick, manager of the Plant Engineering Dept. of General Electric's Lamp Division at Nela Park, Cleveland, retired from active service March 31. He will be succeeded by **Herman M. Filkins,** who has been serving as assistant manager of the department for the past year.

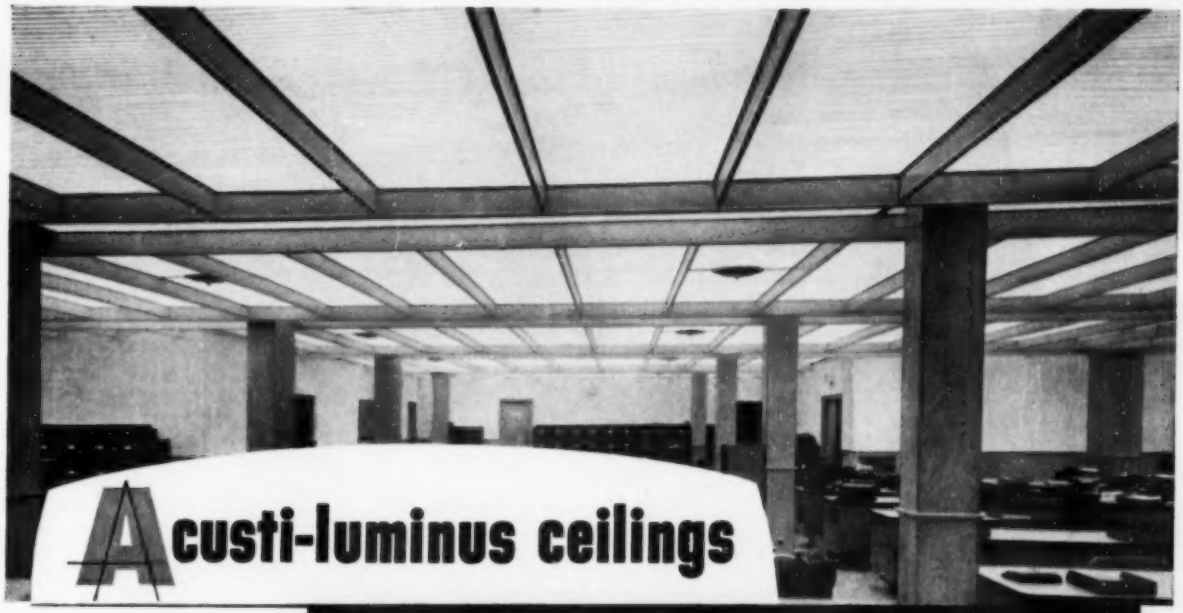
Wakefield Lighting Ltd., London, Ont., has made three additions to the sales-engineering staff. Pacific Distributing Co., Ltd., Vancouver, B. C., will represent Wakefield under the direction of **E. W. Thompson,** sales manager. **A. H. R. Louden,** Edmonton, Alta., will be in charge of that area. **J. W. Henson** will represent the company in Toronto. The London plant at 395 Wellington Rd. South, which had its official opening April 27, will be under the direction of **Ralph A. Yates,** vice-president and general manager of the company.

Professor D. M. Finch of the University of California is doing official testing on the West Coast for the Electrical Testing Laboratories, Inc. of New York City.

Advance Transformer Co., Chicago, Ill., has announced the election of **Max D. Orr** as Vice-President in charge of sales. Mr. Orr was formerly general sales manager. Also elected as Vice-President in charge of engineering was **Albert E. Feinberg,** who has been associated with the company since 1946 as chief engineer.

Carl L. Krueger has been named sales manager of Radiant Lamp Corp., Newark, N. J. He was Western District Manager at the company's Hollywood, Calif., office for the past six years.

(Continued on page 25A)



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(Continued from page 22A)

John F. Baker has been appointed district engineer for Westinghouse Lamp Division's North and South Carolina district, with headquarters at the Charlotte, N. C. office. Mr. Baker was formerly assistant regional engineer in Atlanta.

Charles G. Pyle, Executive Director of the National Association of Electrical Distributors is convalescing from recent surgery, and is reported on the way to complete recovery.

Gordon Dille has been named manager of public relations for Westinghouse Electric Corp.'s Lamp Division. Mr. Dille will be responsible for the public relations activities of the headquarters plant in Bloomfield, N. J. and at the plants in Belleville and Trenton, N. J.; Fairmount, W. Va.; Richmond, Ky.; Little Rock, Ark.; Paris, Texas, and Reform, Ala.

The appointment of **Lou Goren,** to the New York sales staff of Smithcraft Lighting Division, Chelsea, Mass., has been announced. Mr. Goren is an active member of the New York Section of I.E.S., currently serving as Chairman of the Program Committee and on the Board of Managers.

The advancement of three members of the sales organization of Westinghouse Lamp Division has been announced. **Charles E. Erb** was named general sales manager; **Russell E. Ebersole,** marketing manager; and **Herbert E. Plishker,** merchandise manager.

Metalcraft Products Co., Inc., Philadelphia, has announced the election of **Fred M. Pyle** to the post of Vice-President in charge of sales and product development.

Bernard Eichwald, 32, president of B. Eichwald and Co., Inc., New York electrical engineers and contractors, has been elected a member of the Young Presidents Organization, a national group comprised of company heads under 40 years of age whose firms do more than a million dollars annual business.

David B. Young and **Lewis A. Steinberg** have been appointed as sales engineers for the Pittsburgh Reflector Co., Pittsburgh, Pa. Both men will handle the complete line of Pittsburgh Permaflector fluorescent and incandescent lighting equipment. Mr. Young, from headquarters in New Orleans, will cover the entire state of Louisiana and Southern Mississippi. Mr. Steinberg, from company home offices in Pittsburgh, will cover Western Pennsylvania, Eastern Ohio and Northern West Virginia.

OBITUARIES

Dr. LeGrand Haven Hardy, one of the nation's authorities on the physiology of the eye, died April 14 of a heart ailment, at the age of 59. Dr. Hardy had for many years been a member of the Society's Committee on Standards of Quality and Quantity for Interior Illumination.

Dr. Hardy was Clinical Professor of Ophthalmology at the College of Physicians and Surgeons of Columbia University and associate attending ophthalmologist of Presbyterian Hospital in New York City. A leader in research of the eye's behavior, he was known for his studies of the eye's response to light and color and its space perception. His most recent publications included a final report on his work for the Office of Naval Research, entitled "The Geometry of Binocular Space Perception," and a new test for detecting defective color vision.

He was a fellow of the American College of Surgeons, the American Medical Association, the New York Academy of Medicine, the American Ophthalmological Society and the Association of Research Ophthalmologists. Dr. Hardy had been president of the American Orthoptic Council since 1938.

Harry E. Ingraham, president of the Holdenline Co., died April 13 at his home in Rocky River, Ohio. Mr. Ingraham had been an active member of the Cleveland Section of I.E.S., since he joined the Society in 1939, serving as Chairman of the Section's Program Committee, and Sustaining Membership Committee, and on the Board of Managers.

S. H. Simonsen, past Chairman of the Southern California Section of I.E.S., passed away recently at the age of 63. Mr. Simonsen who had been with Westinghouse Electric Supply Corp. in Chicago and Los Angeles for many years, and later with Ruby Lighting Corp., had been Chairman of his Section in 1951-1952.

NEW MEMBERS

At the meeting of the I.E.S. Council held in New York, N. Y. on April 10, the following were elected to membership. Names marked * are transfers from Associate Member grade.

ARIZONA CHAPTER

Associate Member:
Morairty, R. F., Arizona Public Service Co., Buckeye, Ariz.

ARK-LA-TEX CHAPTER

Associate Member:
Edge, H. L., Jr., Westinghouse Electric Supply Co., Shreveport, La.

BRITISH COLUMBIA SECTION

Member:
*Doherty, T. H., British Columbia Electric Co. Ltd., Vancouver, B. C.

CAPITAL SECTION

Members:
Bibb, J. S., Graybar Electric Co. Inc., Richmond, Va.
Delano, G. M., City of Richmond, D.P.U., Richmond, Va.
Diggs, E. T., Virginia Electric & Power Co., Norfolk, Va.
Higgins, E. E., Richmond Public Schools, Richmond, Va.
Morris, L. H., P. O. Box 349, Salem, Va.
Peaseley, G. B., Jr., 113 S. 3rd St., Richmond, Va.
Williams, C. V., Richmond Public Schools, Richmond, Va.
Woody, W. H., City of Richmond, D.P.U., Richmond, Va.

Associate Members:
Harris, T. P., Jr., General Electric Supply Corp., Richmond, Va.
McCrone, R. T., General Electric Co., Richmond, Va.
Mason, William, Benjamin Electric Mfg. Co., Richmond, Va.
Roberts, L. W., L. W. Roberts Co., Richmond, Va.
Turner, H. B., Edwin F. Guth Co., Richmond, Va.

CAROLINAS SECTION

Member:
Hulsart, J. J., Electrical Contracting & Engineering Co., Charlotte, N. C.

Associate Member:
Stevens, E. D., Carolina Power & Light Co., Raleigh, N. C.

CENTRAL ILLINOIS CHAPTER

Associate Member:
Carroll, O. O., St. Francis Hospital, Peoria, Ill.

CENTRAL NEW YORK SECTION

Member:
*Goodman, R. H., Crouse Hinds Co., Syracuse, N. Y.

Associate Member:
Sullivan, J. E., Walter E. Daw Co., Syracuse, N. Y.

CHICAGO SECTION

Associate Members:
DeVore, J. C., Public Service Co., Maywood, Ill.
Doberstein, S. A., Chicago Athletic Association, Chicago, Ill.
Kaczmarek, R. L., Benjamin Electric Mfg. Co., Des Plaines, Ill.
Kroger, C. H., Sylvania Electric Products Inc., Melrose Park, Ill.
Laliah, T. P., Holabird & Root & Burgee, Chicago, Ill.
Olsen, K. J., Benjamin Electric Mfg. Co., Des Plaines, Ill.
Unnewehr, L. E., Valparaiso University, Valparaiso, Ind.

CLEVELAND SECTION

Member:
*Saveland, B. W., The Austin Co., E. Cleveland, Ohio.

Associate Members:
Degner, F. B., General Electric Co., Cleveland, Ohio.
Hoermann, E. W., Ohio Edison Co., Akron, Ohio.
Lobas, Mathew, Cleveland Electric Illuminating Co., Cleveland, Ohio.
Rich, W. E., Ohio Edison Co., Akron, Ohio.
Siegel, Lawrence, Luminous Ceilings Inc., Cleveland, Ohio.

CORNHUSKER CHAPTER

Associate Member:
Gandy, M. E., General Electric Supply Co., Omaha, Nebr.

FLORIDA CHAPTER

Associate Members:
Emanuele, G. J., Florida Council for the Blind, Tampa, Fla.
McPherson, F. C., 6417 7th Ave. N., St. Petersburg, Fla.

FOREIGN NON-SECTION

Associate Member:
Cohen, T. I. H., New Era Fluorescent Light (Pty) Ltd., 127 Anderson St., Johannesburg, S. A.

(Continued on page 32A)

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Ask any mechanic who has worked with the Garcy Adjustable Stem Hanger. He'll tell you what a time-saver it is...especially where there are ceiling obstruction or slopes. Ask any maintenance man about the convenience of re-lamping two Starliner fixtures from a single ladder position. For all concerned, Garcy means "Quality...*by design*." Send for complete data sheets.

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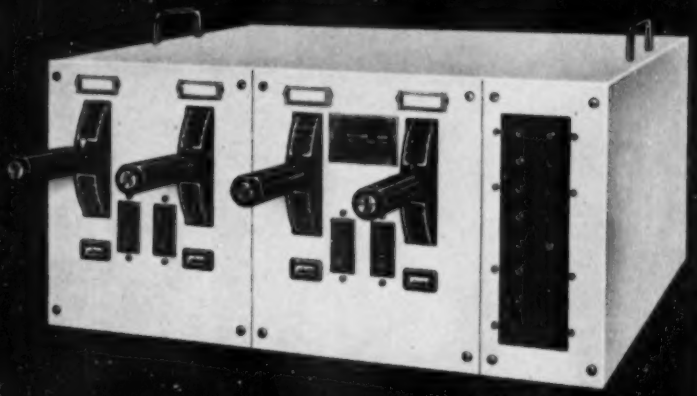

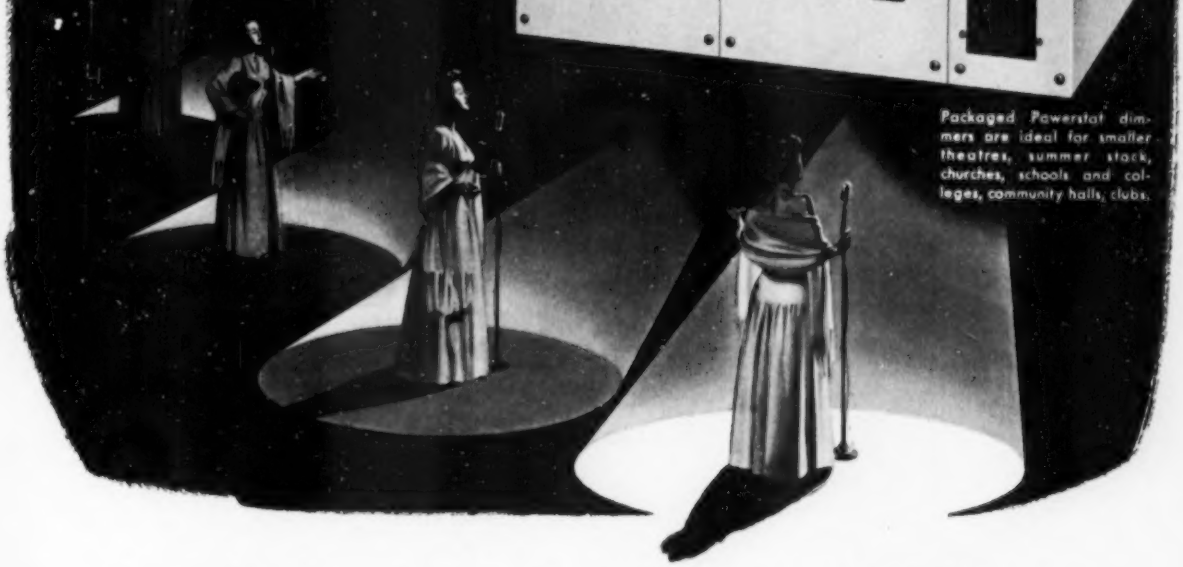

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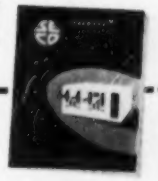

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Brilliant, new Sylvania R-52 Incandescent Reflector Lamps help raise production records, reduce maintenance.

Results show that R-52 Reflector Lamps greatly improve factory seeing conditions and enable workers to step up production.

The special reflector on the inner surface of this lamp is designed to concentrate a clear, bright light directly on the working area. And, because the reflector is sealed in, it cannot become smudgy from dust or smoke. The Sylvania R-52 permits an upward component of cheerful, over-all reflected light. Thus, you get a better maintained level of light . . . at low maintenance costs.

Sylvania R-52 Reflector Lamps are available in 500-watt and 750-watt sizes. For full details call your Sylvania Representative or write to Dept. 4L-3505, Sylvania today.

SYLVANIA

Sylvania Electric Products Inc. 1740 Broadway, New York 19, N. Y.

In Canada: Sylvania Electric (Canada) Ltd.,
University Tower Building, St. Catherine St., Montreal, P. Q.

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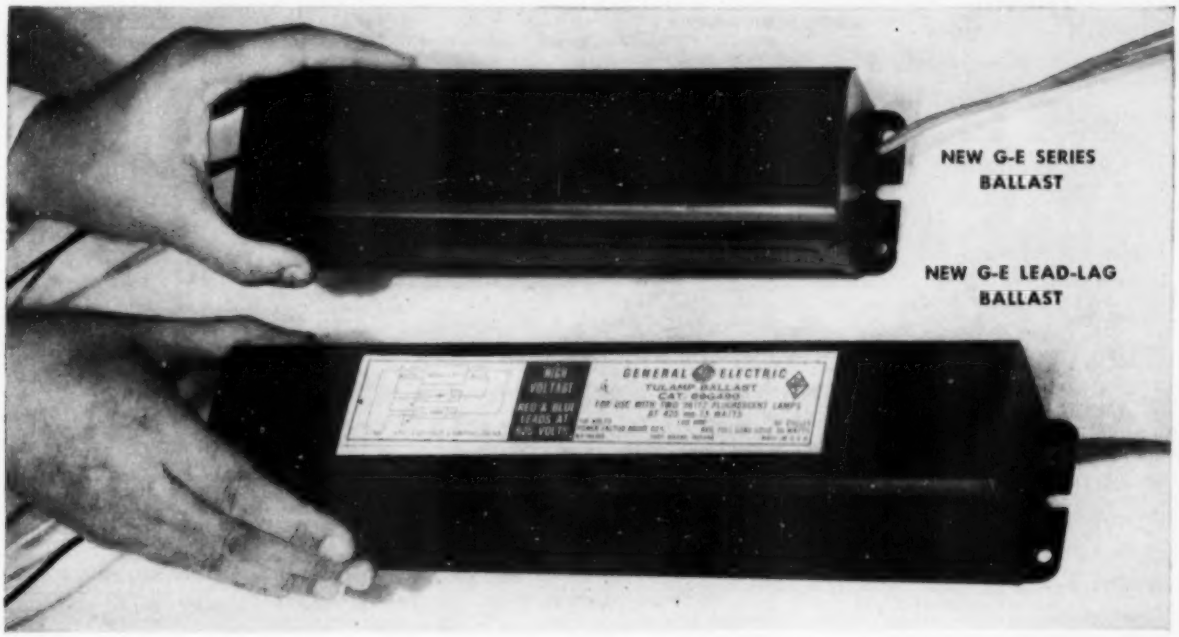

New G-E Series and Lead-lag Ballasts ... Compare and Choose for Yourself

Here is a comparison of G.E.'s two new ballasts for operation of 96T12 lamps at 425 ma. Catalog No. 89G496 is the newly designed series ballast—smaller, lighter, quieter. Catalog No. 89G490 is the similarly redesigned lead-lag ballast.

BOTH BALLASTS ARE CBM CERTIFIED and contain that full measure of extra quality which G-E engineers into every ballast, but the series ballast, by its inherent design characteristics, gives you more value for your dollar. However, if you prefer lead-lag instead of series, the new lead-lag ballast has been designed to give you the most value compared to other lead-lag ballasts.

THE SERIES BALLAST gives you equivalent performance, in accordance with lamp specifications, and offers a substantial savings in cost and size. At right is a comparison of these two General Electric ballasts. The major areas of difference are printed in bold face. You can see that the series is less expensive, uses less line current, has less wattage loss, weighs less, has a quieter sound rating, is smaller.

Compare and choose for yourself.

For further information on either series or lead-lag ballasts, write to Section 401-6, General Electric Co., Schenectady 5, New York.

SERIES 89G496		LEAD-LAG 89G490
73	Nominal lamp watts	73
110–125	Circuit voltage	110–125
60	Frequency	60
1.55	**Line Current in Amps**	**1.60**
.425	Lamp Current in Amps	.425
28	**Watts Loss**	**36**
90%	Min line power factor	90%
$10.15	**List Price Each**	**$12.60**
6	No. Units per Package	6
65	**Approximate Ship weight**	**74**
D	**Sound Rating**	**E**
11¾	**Over-all length**	**14⅜**
11 9/64	**Mounting Length**	**13¾**

Progress is our most important product

GENERAL ELECTRIC

(Continued from page 25A)

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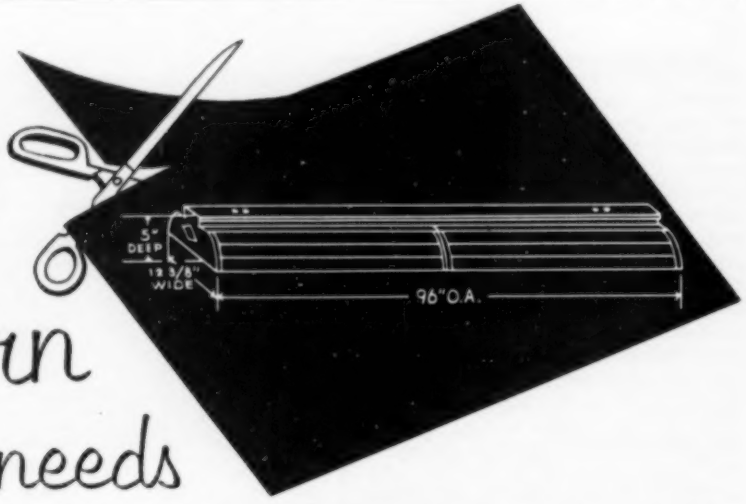
(Continued on page 34A)

We can Cut the Pattern to suit your needs



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From the very first shears that cut the metal to size, L & P fluorescent and slimline fixtures are made right in our own plant, every step of the way. That's why we can assure you of the right light for each specific job.

We're equipped to assist you in planning and research—and then to go ahead and manufacture the complete fixtures to your particular requirements.

For the quality of "custom-made" at the cost of standard fixtures, write or wire for our catalog and prices today Distributed by Electrical Wholesalers Only.

how much light for a dollar?

In lighting, first costs are not real costs! Real costs are the sum of the first costs including installation *and operating and maintenance expenses during the life of the system.*

Time and again, fewer Smithcraft lighting units are required to produce recommended lighting results. Because fewer Smithcraft units are required, your first cost is lower, but your really big savings are in the lower power costs and lower maintenance costs that go with fewer units.

On a typical factory installation lighting 20,000 square feet of floor space, for example, the Smithcraft A. L. S. Factory Lighting Unit will save roughly $8,000 over a ten-year period, when compared with a typical industrial fixture with 6-10% up-lighting (design and performance conforming with RLM standards). So, it's possible to enjoy the benefits of the finest lighting that money can buy and effect really substantial savings at the same time, simply by buying the right fixture.

Ask us to send you our A. L. S. Factory Lighting Folder.

PHOTOGRAPH SHOWS INSTALLATION OF 4450 SMITHCRAFT A. L. S. UNITS LIGHTING 397,000 SQ. FT. TO 75 FOOTCANDLES.

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Public utility lighting specialist; 25 years' experience in sales and all types of lighting layout and design. Accustomed to public appearances. Prefer Mid-West. 44 years old; married. Address Box 208, Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

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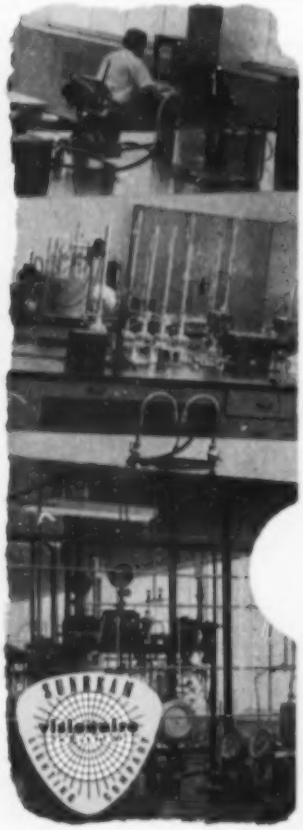

The Research Center of the Standard Oil and Gas Company, Tulsa, Okla., is one of the most modern petroleum research laboratories in the world. Over 2450 Sunbeam fluorescent lighting fixtures of various types were installed in offices, laboratories and cafeteria. Most of the installation consists of Sunbeam's recessed troffers, #5600. T-Bar mounted at a height of 10 feet in acoustical tile ceilings, the continuous rows of louver shielded fixtures provide 55 footcandles of even illumination. Vapor-proof type units light the kitchen.

SUNBEAM LIGHTING COMPANY. 777 East 14th Pl., Los Angeles 21, California

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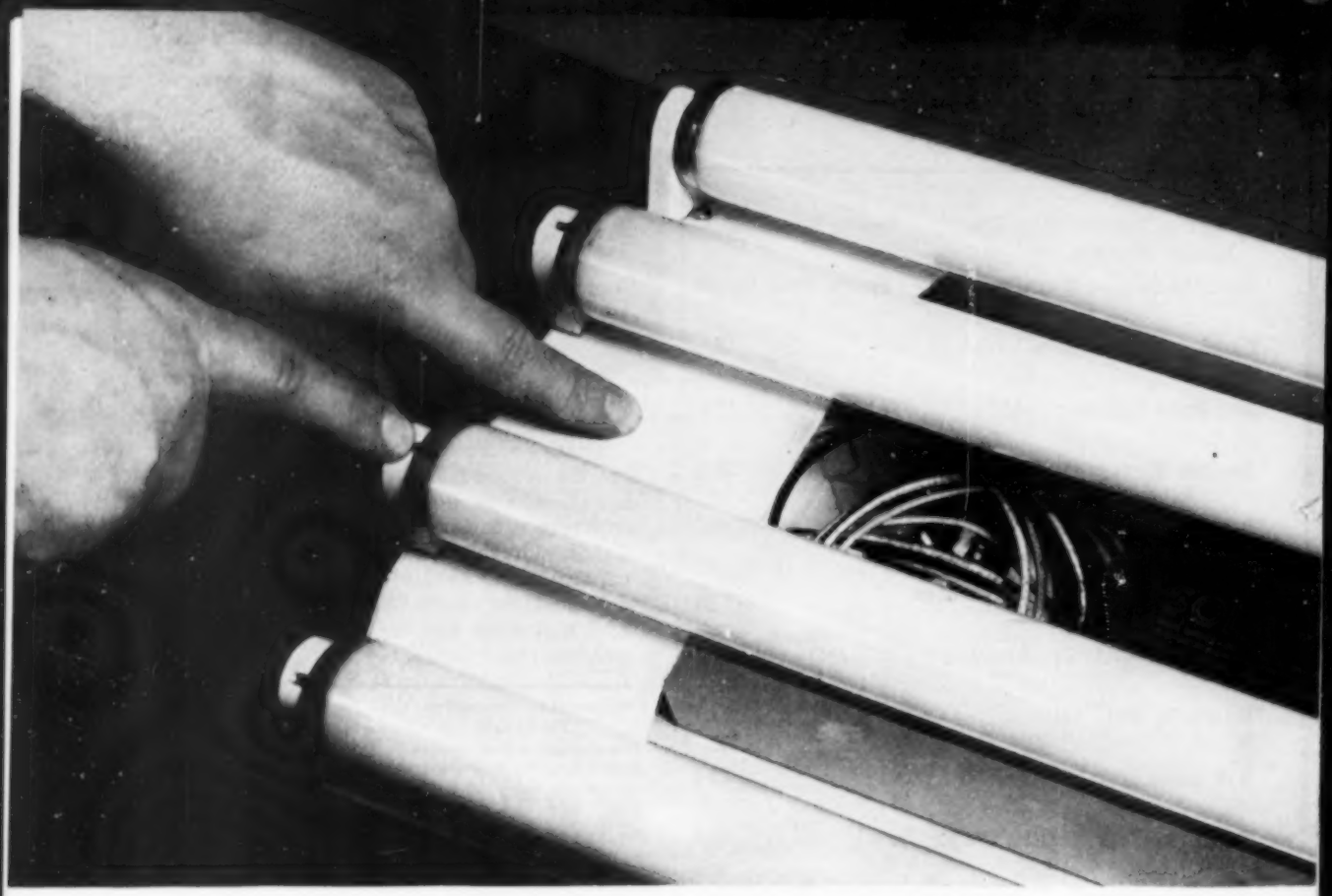

300 volts from lamp to ground for dependable starting of rapid-start lamps with Sola Constant Wattage Ballasts

The voltage from the electrode in a rapid-start fluorescent lamp to the grounded fixture (an important starting aid) is important for dependable starting. The higher this voltage, the more positive starting will be. Conventional, autotransformer-type rapid-start ballasts provide only 180v across lamp-to-ground. Sola Constant Wattage Ballasts provide 300v with *perfect safety*.

This extra 60% voltage from lamp to ground is one of the advantages that results from Sola's patented, double-wound, constant wattage circuit. In addition, lumen output is maintained constant within ±2% regardless of line voltage fluctuations from 106-130v.

Close the switch — a Sola ballasted rapid-start fixture will start even under adverse conditions of temperature, humidity and lamp age. This positive starting characteristic also prolongs lamp starting life.

If you manufacture, fixtures, or specify, operate, or maintain lighting installations, look into the benefits of a constant wattage ballasted rapid-start system. A Sola sales engineer will be happy to give you all the facts.

Reduces relamping . . . keeps lumen output constant

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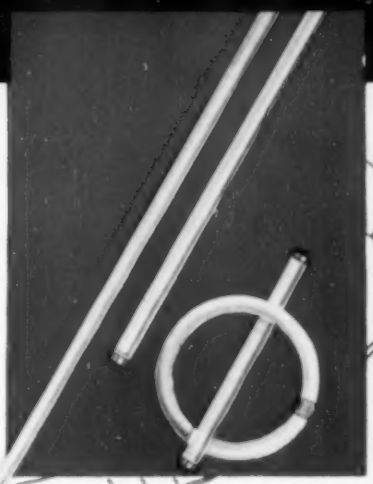
CBM Certified Ballasts are Tailored to the Tube

. . . to make your lighting dollar go farther



The heart of a fluorescent fixture is the Ballast.

Best lighting performance is assured by accurately matching ballasts to fluorescent tube requirements.

CERTIFIED BALLASTS are so matched. Built to exacting specifications designated by the Certified Ballast Manufacturers,* tested, checked and Certified by ETL, CERTIFIED BALLASTS truly are "Tailored to the Tube!"

That's why CERTIFIED BALLASTS assure:

LONG LAMP LIFE — FULL LIGHT OUTPUT
LONG BALLAST LIFE — FREEDOM FROM OVERHEATING
QUIET, TROUBLE-FREE OPERATION

And that's why, today, the large majority of fluorescent fixtures for general lighting service are equipped with CBM Certified Ballasts.

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**Nine leading manufacturers make CBM CERTIFIED BALLASTS.*

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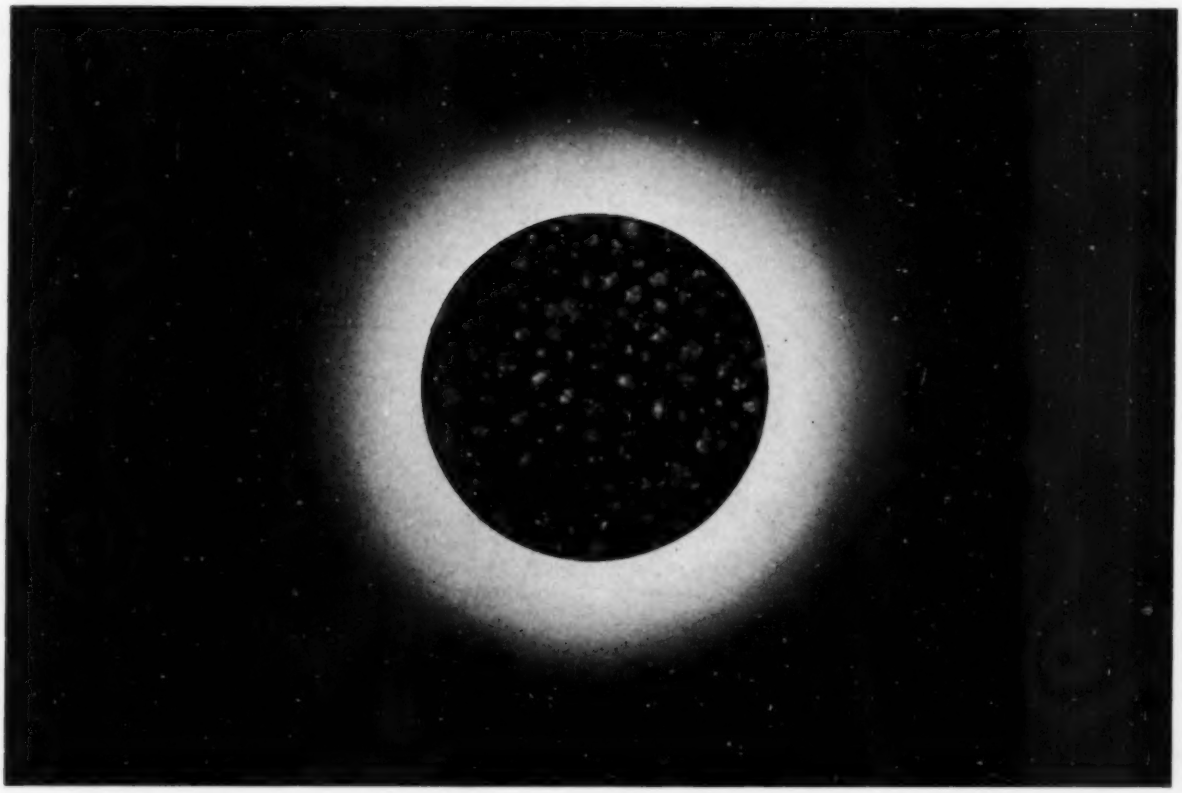

You are looking through a 2600 power microscope at minute particles of phosphor powder. This powder coats the inside of your fluorescent lamps and controls the light output. For peak light output, both initially and throughout lamp life, the particles must be uniform to within a few microns. This uniformity, visible in the photomicrograph above, is one reason Westinghouse Standard Fluorescent Lamps age only 20% after 7500 hours of daily use. See for yourself how Westinghouse Lamps start bright, and stay bright even after 7500 hours . . . by trying some next time you order.

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